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(54) **SUGAR BEET JUICE PRODUCTION AND PROCESSING**

(57) The present invention relates to an improved method for the preparation of filtered sugar beet juice, clarified sugar beet juice, sugar beet syrup, crystalline sugar and sugar beet molasses from raw sugar beet material and to the filtered sugar beet juice, clarified sugar beet juice, sugar beet syrup, crystalline sugar and sugar beet molasses obtainable by such improved method. The improved methods do not employ alkalization agents,

and the temperature of the sugar beet material during the process is only moderate. The filtered sugar beet juice, clarified sugar beet juice, sugar beet syrup, crystalline sugar and sugar beet molasses are characterized by low concentrations of impurities such as pyrazines and pyrrolidone carbonic acid and increased concentrations of for example phosphate.

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**Description****Field of the invention**

**[0001]** The present invention relates to an improved method for the preparation of filtered sugar beet juice, clarified sugar beet juice, sugar beet syrup, crystalline sugar and sugar beet molasses from raw sugar beet material and to the filtered sugar beet juice, clarified sugar beet juice, sugar beet syrup, crystalline sugar and sugar beet molasses obtainable by such improved method. The present invention further relates to the use of the sugar beet syrup or sugar beet molasses as a food product for human consumption or as a sweetener in food products for human consumption.

**Background art**

**[0002]** The production of crystallized sugar and related products (such as syrups) from sugar beets conventionally comprises performing a pre-treatment step, consisting of thermal cell disintegration, on washed and sliced fresh sugar beets. Sucrose is extracted from the thermally treated sugar beets by a warm aqueous diffusion process, by pressing, or by combinations of these techniques to obtain so-called 'raw juice'. Such techniques require prolonged exposure of the material to elevated temperatures (above 70 °C). The thermal treatment results in the denaturation of the cell wall structure, which in turn leads to a high content of colloidal impurities in the raw juice and the induction of chemical and enzymatic reactions, eventually leading to the presence of undesirable products and coloration of the raw juice. The raw juice thus needs to be subjected to one or more purification steps to yield a purified juice, so-called 'thin juice'. High-temperature (120°C or more) evaporation of the thin juice results in so-called 'thick juice'. Crystallization of sucrose from thick juice finally yields sucrose crystals and molasses.

**[0003]** Impurities resulting from the thermal treatment include proteins, pectins, pyrazines, coagulated proteins and/or non-proteins (colloids), colorants such as melanins, melanoidins, caramels and HADP, which deteriorate the juice purity and complicate subsequent process steps. Although other processes such as sulfitation or active carbon filtration are known, purification of some of these impurities (mostly large molecular weight impurities) in large-scale manufacturing is generally done by one or more liming steps and carbonation. In a liming step the raw juice is alkalized by the addition of milk of lime. This leads to neutralization of organic and inorganic acids present in the extract and to the formation of insoluble calcium salts, such as phosphates, oxalates, citrates and sulfates. Proteins as well as colloidal non-sugars like pectin will coagulate, facilitating their removal by filtration. In the subsequent carbonation step, calcium hydroxide that is not consumed in the liming step is converted to calcium carbonate by the introduction of carbon dioxide. These purification steps require large amounts of lime. The use of large amounts of lime not only negatively influences the costs of the process but is also particularly unfavorable from an environmental point of view.

**[0004]** Additionally, the heat and liming applied in conventional processes have a negative impact on the quality and/or the taste of the obtained products. One class of compounds that is of particular interest in this regard are the pyrazines. Pyrazines are formed in alkaline conditions in the presence of glucose and amino acids, which have great chemical reactivity with respect to carbonyl compounds, presumably through Maillard type reactions. The compound 2,5-dimethyl pyrazine has been identified as one of the major contributors to the characteristic off-odour of beet sugar.

**[0005]** Purification of raw juice can easily result in highly refined products in the sense that nutrients that are considered impurities in the production of crystallized sugar and sugar beet syrup but are nevertheless valuable to consumers, such as proteins, are removed. Consumers increasingly associate highly refined food products with less healthy diets.

**[0006]** In the past decade, attention has been given to the development of non-thermal pre-treatment methods, for example electrical (based on the pulsed electric field (PEF) technique), physical (high pressure, supercritical carbon dioxide), biological (fermentation) or chemical (liming as pre-treatment, acidification). So far, none of these techniques have been implemented in industrial processes, either because the required quality of the end-products could not be achieved and/or implementation is not feasible for economic or environmental reasons (e.g. because it would significantly increase energy expenditure or does not provide sufficient yields).

**[0007]** WO99/64634A1 concerns pulsed electric field treatment of sugar beet cossettes followed by low-temperature extraction and pressing.

**[0008]** A. B. Jemai et al., J. Food Eng. 59 (2003), pp 405-412, disclose the use of pulsed electric fields in enhanced leaching from sugar beets.

**[0009]** H. Mhemdi et al., J. Food Eng. 168 (2016), pp 166-172, disclose a sugar beet sucrose extraction process through the treatment of sliced beets with a pulsed electric field at 10°C followed by pressing, resulting in an expressed juice. Further extraction of the pressed slices at 30 or 70 °C is possible although not mandatory.

**[0010]** K.G. Loginova et al., J. Food Eng. 102 (2011), pp 340-347, disclose a sugar beet sucrose extraction process through the treatment of sliced beets with a pulsed electric field followed by extraction at 30°C.

**[0011]** K.G. Loginova et al., J. Food Eng. 106 (2011), pp 144-151, disclose a sugar beet extraction process through the treatment of sliced beets with a pulsed electric field followed by extraction at 30°C or 50°C and ultrafiltration with

membranes having molecular weight cut-offs of 10, 30 or 100 kDa.

**[0012]** US2013/0202751A1 concerns a method for the treatment of vegetable tissues with pulsed electric field in order to extract therefrom a vegetable substance such as a juice. It is described that in case of beet juice, it is generally necessary to employ a subsequent phase of lime and carbon dioxide purification.

**[0013]** It is an object of the present invention to provide an improved method for the preparation of filtered beet juice, clarified beet juice and sugar beet syrup from raw sugar beet material, which has a reduced environmental impact and/or results in less impurities while still being economically feasible.

**[0014]** It is another object of the present invention to provide an improved method wherein the filtered beet juice, clarified beet juice or sugar beet syrup is further processed to sugar beet molasses and crystallized sugar, which has a reduced environmental impact and/or result in less impurities, while still being economically feasible.

**[0015]** It is another object of the present invention to provide sugar beet syrups, sugar beet molasses and crystallized sugar with improved nutritional and/or organoleptic properties.

### Summary of the invention

**[0016]** According to a first aspect of the invention a method for the preparation of sugar beet syrup from whole sugar beet is provided, said method comprising the distinct steps of:

a) providing whole sugar beets;

b) reducing the size and releasing juice from the sugar beet material by subjecting the whole sugar beets to:

- shredding, slicing or milling, followed by a treatment selected from the group consisting of pulsed electric field (PEF) treatment, fermentation, acidification, freezing and thawing, and combinations thereof;
- pulsed electric field, followed by shredding, slicing or milling; or
- milling,

resulting in a treated sugar beet material comprising sugar beet juice and pulp or mush;

c) separating sugar beet juice from pulp or mush by subjecting the treated sugar beet material obtained in step b) to a coarse physical separation, wherein the coarse physical separation at least comprises passing the sugar beet juice over a solid filter medium with mesh openings between larger than 10  $\mu\text{m}$  and 2000  $\mu\text{m}$ , and preferably comprises one or more pressing cycles with optional soaking prior to applying said solid filter medium, resulting in filtered sugar beet juice with a sucrose content of between 5 and 30 wt.%;

d) optionally subjecting the filtered sugar beet juice of step c) to a fine physical purification step, resulting in clarified sugar beet juice with a sucrose content of between 5 and 30 wt.%;

e) subjecting the filtered sugar beet juice of step c) or the clarified sugar beet juice of step d) to a concentration step resulting in sugar beet syrup with a sucrose content of between 30 and 86 wt.%, preferably between 60 and 80 wt.%, more preferably between 63 and 75 wt.%, even more preferably between 67 and 71 wt.%,

wherein no alkalization agent is employed, wherein the temperature of the sugar beets, sugar beet material, treated sugar beet material, sugar beet juice and filtered sugar beet juice in steps a) to c) does not exceed 60°C, preferably does not exceed 50°C, more preferably does not exceed 40°C, even more preferably does not exceed 30°C, and wherein the temperature of the clarified sugar beet juice in step d) does not exceed 70°C, preferably does not exceed 60°C, more preferably does not exceed 50°C, even more preferably does not exceed 40°C.

**[0017]** In very preferred embodiments, the methods do not comprise membrane filtration using a membrane with a pore size of 0.1  $\mu\text{m}$  or smaller, and do not comprise membrane filtration using a membrane having a cut off of 102 kDa or smaller.

**[0018]** In very preferred embodiments, the methods do not comprise ultrafiltration, nanofiltration and reverse osmosis.

**[0019]** In very preferred embodiments, the methods do not comprise ultrafiltration.

**[0020]** The methods provided herein have the advantage that the use of a step wherein juice is released from the sugar beet material at reduced temperature provides significant energy efficiency while they do not require the use of additional chemicals, such as lime, making the methods according to the invention green alternatives to conventional processes. The elimination of an alkalization step and the reduced thermal load result in cost-savings, improved process efficiency and products with improved characteristics, such as improved organoleptic properties.

**[0021]** The inventors have unexpectedly found that costly membrane purification steps using membranes with a pore size of 0.1  $\mu\text{m}$  or smaller or membranes having a cut off of 102 kDa or smaller, such as ultrafiltration, nanofiltration and reverse osmosis, can be dispensed with, whereas nutritionally enriched products with still good organoleptic properties can be obtained.

**[0022]** In a second aspect, the invention concerns the sugar beet syrup obtainable by this method.

**[0023]** In preferred embodiments, the method further comprises subjecting the sugar beet syrup of step e) to a further concentration step f) resulting in crystallized sugar and sugar beet molasses.

**[0024]** In a third aspect, the invention concerns the crystallized sugar and sugar beet molasses obtainable by this method.

**[0025]** The inventors surprisingly found that, as compared to conventional processes for the preparation of thin juice, thick juice, crystalline sugar and molasses from sugar beet using high temperature extraction and liming at alkaline conditions, the methods of the invention result in filtered sugar beet juice, clarified sugar beet juice, sugar beet syrup, crystalline sugar and sugar beet molasses having advantageous compositions in terms of low concentrations of certain unwanted ingredients and increased concentrations of certain valuable ingredients. More in particular, without wishing to be bound by any theory, it is believed that refraining from a significant thermal load results in a sugar beet juice having a decreased concentration of pyrazines, such as 2,5-dimethylpyrazine, 2-ethyl-3-methylpyrazine and 2,3,5-trimethylpyrazine, based on total dissolved dry solids weight, as compared to a conventional process for producing raw juice from sugar beets. Moreover, again without wishing to be bound by any theory, it is believed that refraining from alkalization, such as liming, during purification, results in a filtered sugar beet juice, clarified sugar beet juice and sugar beet syrup having a decreased concentration of pyrrolidone carbonic acid and an increased concentration of oxalate and phosphate, based on total dissolved dry solids weight as compared to a conventional process for producing thin juice and thick juice from sugar beet raw juice.

**[0026]** Accordingly, in a fourth aspect of the invention, sugar beet syrup is provided, characterized by between 500 and 7000 mg/kg, preferably between 800 and 5000 mg/kg, more preferably between 1000 and 3500 mg/kg of phosphate, and one or more of the following properties, wherein the concentrations are based on total dissolved dry solids weight:

- i) substantially free or free of 2,5-dimethylpyrazine;
- ii) substantially free or free of 2-ethyl-3-methylpyrazine;
- iii) substantially free or free of 2,3,5-trimethylpyrazine;
- iv) less than 500 mg/kg, preferably less than 450 mg/kg, more preferably less than 400 mg/kg, even more preferably less than 350 mg/kg of sulfate;
- v) less than 600 mg/kg, preferably less than 500 mg/kg, more preferably less than 400 mg/kg, even more preferably less than 370 mg/kg of pyrrolidone carbonic acid;
- vi) between 1000 and 7000 mg/kg, preferably between 1500 and 5000 mg/kg, more preferably between 2000 and 4000 mg/kg, even more preferably between 2500 and 3500 mg/kg of oxalate; and
- vii) more than 500 mg/kg, preferably more than 650 mg/kg, more preferably more than 850 mg/kg, even more preferably more than 1000 mg/kg, of the combined amount of histidine and glutamine.

**[0027]** In a preferred embodiment, the sugar beet syrup is characterized by between 500 and 7000 mg/kg, preferably between 800 and 5000 mg/kg, more preferably between 1000 and 3500 mg/kg of phosphate, and:

- a combination of i), ii) and iii);
- a combination of i) - iv);
- a combination of i) - v);
- a combination of i) - vi);
- a combination of i) - vii); or
- a combination of iv) - vii).

**[0028]** Without wishing to be bound by any theory, it is believed that refraining from a significant thermal load results, after crystallization, in sugar beet molasses having a decreased concentration of pyrazines, such as 2,5-dimethylpyrazine, 2-ethyl-3-methylpyrazine and 2,3,5-trimethylpyrazine, based on total dissolved dry solids weight, as compared to a conventional process for producing molasses from sugar beets. Moreover, again without wishing to be bound by any theory, it is believed that refraining from alkalization, such as liming, during purification, results in sugar beet molasses having a decreased concentration of pyrrolidone carbonic acid and an increased concentration of oxalate and phosphate, based on total dissolved dry solids weight, as compared to a conventional process for producing molasses from sugar beets.

**[0029]** In a fifth aspect of the invention, sugar beet molasses is provided, characterized by between 100 and 50000 mg/kg, preferably between 1000 and 40000 mg/kg, more preferably between 5000 and 30000 mg/kg, still more preferably between 10000 and 25000 mg/kg of phosphate, and one or more of the following properties, wherein the concentrations are based on total dissolved dry solids weight:

- i) substantially free or free of 2,5-dimethylpyrazine;
- ii) substantially free or free of 2-ethyl-3-methylpyrazine;

- iii) substantially free or free of 2,3,5-trimethylpyrazine;  
 iv) less than 11000 mg/kg, preferably less than 9000 mg/kg, more preferably less than 7000 mg/kg, even more preferably less than 5000 mg/kg of sulfate;  
 v) less than 8000 mg/kg, preferably less than 7500 mg/kg, more preferably less than 7000 mg/kg, even more preferably less than 6500 mg/kg, still more preferably less than 6000 mg/kg of pyrrolidone carbonic acid;  
 vi) between 1000 and 100000 mg/kg, preferably between 3000 and 80000 mg/kg, more preferably between 9000 and 70000 mg/kg, even more preferably between 12000 and 60000 mg/kg, still more preferably between 15000 and 50000 mg/kg of oxalate; and  
 vii) more than 300 mg/kg, preferably more than 600 mg/kg, more preferably more than 900 mg/kg, even more preferably more than 1200 mg/kg, of the combined amount of histidine and glutamine.

**[0030]** In a preferred embodiment, the sugar beet molasses is characterized by between 100 and 50000 mg/kg, preferably between 1000 and 40000 mg/kg, more preferably between 5000 and 30000 mg/kg, still more preferably between 10000 and 25000 mg/kg of phosphate, and:

- a combination of i), ii) and iii);
- a combination of i) - iv);
- a combination of i) - v);
- a combination of i) - vi);
- a combination of i) - vii); or
- a combination of iv) - vii).

**[0031]** Again not wishing to be bound by any theory, it is believed that refraining from a significant thermal load results, after crystallization, in crystallized sugar having a decreased concentration of pyrazines, such as 2,5-dimethylpyrazine, 2-ethyl-3-methylpyrazine and 2,3,5-trimethylpyrazine, based on total dry solids weight, as compared to a conventional process for producing crystallized sugar from sugar beets.

**[0032]** In a sixth aspect of the invention, crystallized sugar characterized by the following properties, wherein the concentrations are based on total dry solids weight, is provided:

- i) substantially free or free of 2,5-dimethylpyrazine;  
 ii) substantially free or free of 2-ethyl-3-methylpyrazine;  
 iii) substantially free or free of 2,3,5-trimethylpyrazine; or  
 iv) a combination of i), ii) and iii).

**[0033]** A seventh aspect of the invention concerns the use of the sugar beet syrup or sugar beet molasses as defined herein or the sugar beet syrup or sugar beet molasses obtainable by the processes as defined herein as a food product for human consumption or as a sweetener in food products for human consumption, such as in liquorice, cereal bars and bakery products.

**[0034]** These and other aspects of the invention, will become apparent to those of average skill in the art on the basis of the following detailed description and examples.

## Brief description of the figures

### [0035]

- Figure 1: UV absorption spectrum of the PEF-beet syrup 2 and conventional thick juice tested in Example 8.  
 Figure 2: Visible absorption spectrum of the PEF-beet syrup 2 and conventional thick juice tested in Example 8.  
 Figure 3: Schematic overview of a first embodiment of a method according to the invention (as used in Example 9) to obtain clarified sugar beet juice, sugar beet syrup, sugar beet molasses and crystallized sugar from sugar beet.  
 Figure 4: Schematic overview of a second embodiment of a method according to the invention (as used in Example 10) to obtain filtered sugar beet juice, sugar beet syrup, sugar beet molasses and crystallized sugar.  
 Figure 5: Schematic overview of a third embodiment of a method according to the invention (as used in Example 11) to obtain filtered sugar beet juice, sugar beet syrup, sugar beet molasses and crystallized sugar from sugar beet according to the invention.  
 Figure 6: Schematic overview of a fourth embodiment of a method according to the invention (as used in Example 12) to obtain filtered sugar beet juice, sugar beet syrup, sugar beet molasses and crystallized sugar from sugar beet according to the invention.  
 Figure 7: Schematic overview of a conventional manufacturing process for the production of raw juice, thin juice,

thick juice, crystallized sugar and sugar beet molasses.

### Detailed description of the invention

**[0036]** A first aspect of the invention concerns a method for the preparation of filtered sugar beet juice or clarified sugar beet juice from whole sugar beet, said method comprising the distinct steps of:

- a) providing whole sugar beets;
- b) reducing the size and releasing juice from the sugar beet material by subjecting the whole sugar beets to:

- shredding, slicing or milling, followed by a treatment selected from the group consisting of pulsed electric field (PEF) treatment, fermentation, acidification, freezing and thawing, and combinations thereof;
- pulsed electric field, followed by shredding, slicing or milling; or
- milling,

resulting in a treated sugar beet material comprising sugar beet juice and pulp or mush;

c) separating sugar beet juice from pulp or mush by subjecting the treated sugar beet material obtained in step b) to a coarse physical separation, wherein the coarse physical separation at least comprises passing the sugar beet juice over a solid filter medium with mesh openings between above 10  $\mu\text{m}$  and 2000  $\mu\text{m}$ , and preferably comprises one or more pressing cycles with optional soaking prior to applying said solid filter medium, resulting in filtered sugar beet juice with a sucrose content of between 5 and 30 wt.%;

d) optionally subjecting the filtered sugar beet juice of step c) to a fine physical purification step, resulting in clarified sugar beet juice with a sucrose content of between 5 and 30 wt.%,

wherein no alkalization agent is employed, wherein the temperature of the sugar beets, sugar beet material, treated sugar beet material, sugar beet juice and filtered sugar beet juice in steps a) to c) does not exceed 60°C, preferably does not exceed 50°C, more preferably does not exceed 40°C, even more preferably does not exceed 30°C, and wherein the temperature of the clarified sugar beet juice in step d) does not exceed 70°C, preferably does not exceed 60°C, more preferably does not exceed 50°C, even more preferably does not exceed 40°C.

**[0037]** In a very preferred embodiment, the method does not comprise membrane filtration using a membrane with a pore size of 0.1  $\mu\text{m}$  or smaller, and does not comprise membrane filtration using a membrane having a cut off of 102 kDa or smaller.

**[0038]** In a very preferred embodiment, the method does not comprise ultrafiltration, nanofiltration and reverse osmosis.

**[0039]** In a very preferred embodiment, the method does not comprise ultrafiltration.

**[0040]** In preferred embodiments, the method to produce filtered sugar beet juice or clarified sugar beet juice as defined herein is a continuous process.

**[0041]** In preferred embodiments, the whole sugar beets provided in step a) are washed sugar beets from which adhering dirt and soil is removed.

**[0042]** As used herein, whole sugar beet may refer to sugar beet inclusive of stem and leaves or sugar beet devoid of stem and/or leaves.

**[0043]** Slicing the whole sugar beet may be performed by any suitable means known to the person skilled in the art, such as a drum slicer, a disc slicer, chopper or cutter. In embodiments, slicing the sugar beet results in an average product thickness of 0.5 - 10 mm, preferably 1 - 5 mm.

**[0044]** Shredding the whole sugar beet may be performed by any suitable means known to the person skilled in the art, such as crushing, grinding, lump breaking, chipping and grating. In embodiments, shredding the whole sugar beet results in shreds with an average size of 1 - 40 mm, preferably 2 - 8 mm.

**[0045]** Milling the whole sugar beet may be performed by any suitable means known to the person skilled in the art, such as hammer milling, pin milling, roll milling and crushing or pulverising using a disintegrator, preferably hammer milling. In embodiments, milling the whole sugar beet results in particulate material with an average particle size of 1 - 5 mm, preferably 1 - 3 mm.

**[0046]** In embodiments wherein in step b) a size reduction is followed by a treatment selected from the group consisting of pulsed electric field treatment, fermentation, acidification, freezing and thawing, and combinations thereof, further size reduction may be performed after said treatment selected from the group consisting of pulsed electric field treatment, fermentation, acidification, freezing and thawing, and combinations thereof.

**[0047]** Likewise, in embodiments wherein pulsed electric field treatment is performed on whole sugar beets, followed by shredding, slicing or milling, the whole sugar beets may also be sliced into chunks prior to said pulsed electric field treatment.

**[0048]** The wording '*comprising the distinct steps of*' is to be construed in the non-limiting sense, meaning that the

method can comprise further steps. It is however to be understood that the temperature of the sugar beet material in any steps before step (a) and in between steps (a) to (d) does not exceed 60°C, preferably does not exceed 50°C, more preferably does not exceed 40°C, even more preferably does not exceed 30°C. Likewise, it is to be understood that the sugar beet material in any steps before step (a) and in between steps (a) to (d) is not in contact with alkalization agent.

**[0049]** The word '*distinct*' in '*comprising the distinct steps of*' means that the process steps are different. In other words, as an example, the coarse physical separation step cannot be identical to the fine physical purification step. If the coarse physical separation step comprises more than one process, none of them is identical to the fine physical purification step.

**[0050]** The word '*physical*' in '*coarse physical separation step*' and '*fine physical purification step*' means that these steps are not based on the addition of chemicals to realize the separation or purification. As will be appreciated by those skilled in the art, the term '*chemicals*' does not encompass water, such as plain tap water or condensation water.

**[0051]** In preferred embodiments, the method further comprises subjecting the filtered sugar beet juice of step c) or the clarified sugar beet juice of step d) to a concentration step resulting in sugar beet syrup.

**[0052]** Accordingly, a preferred embodiment of the first aspect concerns a method for the preparation of sugar beet syrup from whole sugar beet, said method comprising the distinct steps of:

a) providing whole sugar beets;

b) reducing the size and releasing juice from the sugar beet material by subjecting the whole sugar beets to:

- shredding, slicing or milling, followed by a treatment selected from the group consisting of pulsed electric field (PEF) treatment, fermentation, acidification, freezing and thawing, and combinations thereof;
- pulsed electric field, followed by shredding, slicing or milling; or
- milling,

resulting in a treated sugar beet material comprising sugar beet juice and pulp or mush;

c) separating sugar beet juice from pulp or mush by subjecting the treated sugar beet material obtained in step b) to a coarse physical separation, wherein the coarse physical separation at least comprises passing the sugar beet juice over a solid filter medium with mesh openings between above 10  $\mu\text{m}$  and 2000  $\mu\text{m}$ , and preferably comprises one or more pressing cycles with optional soaking prior to applying said solid filter medium, resulting in filtered sugar beet juice with a sucrose content of between 5 and 30 wt.%;

d) optionally subjecting the filtered sugar beet juice of step c) to a fine physical purification step, resulting in clarified sugar beet juice with a sucrose content of between 5 and 30 wt.%;

e) subjecting the filtered sugar beet juice of step c) or the clarified sugar beet juice of step d) to a concentration step resulting in sugar beet syrup with a sucrose content of between 30 and 86 wt.%, preferably between 60 and 80 wt.%, more preferably between 63 and 75 wt.%, even more preferably between 67 and 71 wt.%,

wherein no alkalization agent is employed, wherein the temperature of the sugar beets, sugar beet material, treated sugar beet material, sugar beet juice and filtered sugar beet juice in steps a) to c) does not exceed 60°C, preferably does not exceed 50°C, more preferably does not exceed 40°C, even more preferably does not exceed 30°C, and wherein the temperature of the clarified sugar beet juice in step d) does not exceed 70°C, preferably does not exceed 60°C, more preferably does not exceed 50°C, even more preferably does not exceed 40°C, and

- wherein the method does not comprise membrane filtration using a membrane with a pore size of 0.1  $\mu\text{m}$  or smaller, and does not comprise membrane filtration using a membrane having a cut off of 102 kDa or smaller; or
- wherein the method does not comprise ultrafiltration, nanofiltration and reverse osmosis; or
- wherein the method does not comprise ultrafiltration.

**[0053]** In preferred embodiments the method to produce sugar beet syrup as defined herein is a continuous process.

**[0054]** In a very preferred embodiment, step b) comprises or consist of a pulsed electric field treatment. The parameters for the PEF treatment are not particularly limited and any PEF treatment resulting in sufficient cell permeation to enhance sucrose extraction may be used in step b). Preferred PEF treatments utilize an electric field intensity of 10 - 5000 V/cm, preferably 100 - 2500 V/cm, preferably 800 - 2000 V/cm, most preferably 1400 - 1800 V/cm; a total time of pulses of 1  $\mu\text{s}$  - 200 ms, preferably 0.1 ms - 100 ms, most preferably 5 - 10 ms, a pulse frequency of 0.1 - 10000  $\text{s}^{-1}$ , preferably 1 - 5000  $\text{s}^{-1}$ , preferably 10 - 1000  $\text{s}^{-1}$ , most preferably 100 - 300  $\text{s}^{-1}$ , a pulse time of 1 - 300  $\mu\text{s}$ , preferably 2 - 200  $\mu\text{s}$ , preferably 5 - 150  $\mu\text{s}$ , most preferably 10 - 40  $\mu\text{s}$ .

**[0055]** In embodiments of the invention, the PEF treatment comprises the use of an aqueous treatment medium, *i.e.* a liquid which is added to the (optionally shredded, sliced or milled) sugar beet to establish contact and/or enhance conductivity, wherein the conductivity of the aqueous treatment medium is 50 - 2000  $\mu\text{S/cm}$ , preferably 100 - 1900  $\mu\text{S/cm}$ , preferably 200 - 1800  $\mu\text{S/cm}$ , preferably 300 - 1700  $\mu\text{S/cm}$ .

**[0056]** In preferred embodiments, the PEF treatment does not comprise the use of an aqueous treatment medium (so-called dry-PEF). A small amount of water present on the sugar beet material as a result of a washing step is not considered an aqueous treatment medium.

**[0057]** In embodiments of the invention, step b) comprises or consist of acidification, e.g. acidification of the shredded, sliced or milled sugar beets by employing an acid selected from the group consisting of sulfuric acid, phosphoric acid, hydrochloric acid, nitric acid, citric acid, acetic acid, tartaric acid, malic acid, folic acid, fumaric acid, lactic acid, abietic acid, adipic acid, gluconic acid, formic acid, gallic acid, glucono delta-lactone, and combinations thereof, preferably an acid selected from the group consisting of sulfuric acid, hydrochloric acid, nitric acid, lactic acid and combinations thereof. In embodiments, step b) comprises contacting the shredded, sliced or milled sugar beets with an aqueous solution comprising an acid as described herein. In embodiments, step b) comprises contacting the shredded, sliced or milled sugar beets with an aqueous solution comprising an acid as described herein wherein the pH of the aqueous solution is lower than 6.5, preferably lower than 5, preferably lower than 4, most preferably lower than 3.5. In embodiments the pH of the aqueous solution is higher than 0.5, higher than 1, higher than 2, higher than 2.5. In embodiments, step b) comprises contacting the shredded, sliced or milled sugar beets with an aqueous solution comprising an acid as described herein for more than 1 hour, preferably more than 2 hours, preferably more than 5 hours, preferably more than 8 hours.

**[0058]** In preferred embodiments, the method as defined herein does not involve the addition of any chemicals at all, with the exception of the acid used in the acidification treatment of step b).

**[0059]** In embodiments of the invention, step b) comprises or consist of fermentation. In embodiments, step b) comprises fermenting the shredded, sliced or milled sugar beets for at least 1 hour, preferably at least 3 hours, preferably at least 20 hours. In embodiments the fermentation is continued until the pH is in the range of 2 - 6, preferably 3 - 5. In embodiments, fermentation comprises the addition of an inoculum, such as a fermentation inoculum made from naturally acidified sugar beet juice. Hence, acidification and fermentation can be combined.

**[0060]** In preferred embodiments, step b) comprises acidification and fermentation as defined herein earlier. For example, the shredded, sliced or milled sugar beets may be acidified through the combined effect of acid addition and fermentation.

**[0061]** In embodiments of the invention, step b) comprises or consist of freezing and thawing. In embodiments, step b) comprises freezing the shredded, sliced or milled sugar beets at a temperature of less than - 4°C, preferably less than - 10°C, preferably less than - 18°C, for at least 1 hour, preferably at least 1 day, preferably at least 1 week, prior to thawing. In embodiments, the shredded, sliced or milled sugar beets are subjected in step b) to two or more, such as two, three or four freeze-thaw cycles.

**[0062]** In a preferred embodiment of the invention, step b) comprises or consists of milling, preferably hammer milling. In hammer milling, the whole sugar beets are milled to a mush at for example 3000 rpm using a screen with openings between typically 2 and 8 mm, such as 3 mm circular shaped openings.

**[0063]** The coarse physical separation in step c) concerns the macroscopic separation of pulp or mush on the one hand and released juice on the other hand. The coarse physical separation typically does not remove micro- or nano-particles from the released juice. As described, the coarse physical separation at least comprises passing the sugar beet juice over a solid filter medium with mesh openings between above 10 µm and 2000 µm and preferably comprises one or more pressing cycles with optional soaking prior to applying said solid filter medium. The solid filter medium in step c) as defined herein preferably has mesh openings between 80 and 1000 µm, more preferably between 100 and 750 µm, even more preferably between 150 and 500 µm, still more preferably between 200 and 300 µm, such as 250 µm. This filtering step removes particles, including pebbles, that may be harmful to subsequent process steps.

**[0064]** As explained herein before, step c) preferably comprises one or more pressing cycles with optional soaking prior to applying said solid filter medium. Pressing may be performed using any process suitable to separate sugar beet juice from pulp or mush, such as by employing a screw press or basket press equipped with a screen with suitable mesh size, such as 100 µm - 10 mm, preferably 500 µm - 5 mm, more preferably 1 - 2 mm.

**[0065]** In order to attain sugar exhaustion from the pulp or mush, pressing may be combined with soaking (rehydrating or imbibing) in one or more cycles, such as in 2, 3, 4, 5, or 6 cycles.

**[0066]** The wording '*at least comprises*' in step c) is to be construed in the non-limiting sense, meaning that step c) can comprise further coarse physical separation steps. Preferred coarse physical separation steps that can be applied in step c) further comprise one or more selected from cocurrent or countercurrent extraction, static settling, dynamic settling, spiral plate centrifuging, disk stack centrifuging, decanting, screw pressing, plunger pressing, belt pressing, precoat filtration, flotation, shaker screening, hydraulic cyclone separation and hydraulic upflow classification.

**[0067]** In a preferred embodiment, step c) consists of passing the sugar beet juice over a solid filter medium with mesh openings between above 10 µm and 2000 µm.

**[0068]** In an embodiment, step c) consists of one or more pressing cycles with optional soaking followed by passing the sugar beet juice over a solid filter medium with mesh openings between above 10 µm and 2000 µm.

**[0069]** In another preferred embodiment, step c) consists of passing the sugar beet juice over a solid filter medium with mesh openings between above 10 µm and 2000 µm, and subsequently employing one or more selected from



cocurrent or countercurrent extraction, static settling, dynamic settling, spiral plate centrifuging, disk stack centrifuging, decanting, screw pressing, plunger pressing, belt pressing, precoat filtration, flotation, shaker screening, hydraulic cyclone separation and hydraulic upflow classification, preferably disc stack centrifuging.

**[0070]** In another preferred embodiment, step c) consists of one or more pressing cycles with optional soaking followed by passing the sugar beet juice over a solid filter medium with mesh openings between above 10  $\mu\text{m}$  and 2000  $\mu\text{m}$ , and subsequently employing one or more selected from cocurrent or countercurrent extraction, static settling, dynamic settling, spiral plate centrifuging, disk stack centrifuging, decanting, screw pressing, plunger pressing, belt pressing, precoat filtration, flotation, shaker screening, hydraulic cyclone separation and hydraulic upflow classification, preferably disc stack centrifuging.

**[0071]** As is clear from the wording '*coarse physical separation*', and as appreciated by those skilled in the art, step c) does not comprise passing the sugar beet juice over a solid filter medium with mesh openings equal to or smaller than 10  $\mu\text{m}$ .

**[0072]** Concentration of the filtered sugar beet juice of step c) or the clarified sugar beet juice of step d) in step e) can conveniently be performed by evaporation in, for example, a thin film evaporator. The inventors have found that without additional purification steps, such as liming, carbonation and softening, the sugar beet juice of step c) or the clarified sugar beet juice of step d) can be directly concentrated in a falling film evaporator without substantial deposition of impurities on the heat exchanging elements.

**[0073]** The juice temperature in step e) preferably does not exceed 130°C, more preferably does not exceed 112°C, even more preferably does not exceed 105°C.

**[0074]** The maximum temperatures in the distinct process steps may differ. In preferred embodiments, the temperature of the sugar beets, sugar beet material, treated sugar beet material, sugar beet juice and filtered sugar beet juice in steps a) to c) does not exceed 50°C, preferably does not exceed 40°C, more preferably does not exceed 35°C, even more preferably does not exceed 30°C.

**[0075]** In other preferred embodiments, step d) is mandatory and the temperature of the sugar beets, sugar beet material, treated sugar beet material, sugar beet juice and filtered sugar beet juice in steps a) to c) does not exceed 50°C, preferably does not exceed 40°C, even more preferably does not exceed 30°C and the temperature of the clarified sugar beet juice in step d) is between 50 and 70°C. This may require heating the filtered sugar beet juice obtained in step c) in a heat exchanger before applying step d).

**[0076]** In other embodiments, the temperature during steps a) to c) does not exceed 60°C, preferably does not exceed 50°C, more preferably does not exceed 40°C, even more preferably does not exceed 30°C, and the temperature during step d) does not exceed 70°C, preferably does not exceed 60°C, more preferably does not exceed 50°C, even more preferably does not exceed 40°C.

**[0077]** In embodiments, the temperature during steps a) to c) does not exceed 50°C, preferably does not exceed 40°C, more preferably does not exceed 35°C, even more preferably does not exceed 30°C.

**[0078]** In other embodiments, step d) is mandatory and the temperature during steps a) to c) does not exceed 50°C, preferably does not exceed 40°C, even more preferably does not exceed 30°C and the temperature during step d) is between 50 and 70°C. This may require heating the filtered sugar beet juice obtained in step c) in a heat exchanger before applying step d).

**[0079]** In a preferred embodiment, step b) comprises or consist of shredding, slicing or milling followed by pulsed electric field treatment, step c) comprises or consists of one or more pressing cycles with optional soaking followed by filtration over a solid filter medium with mesh openings between above 10  $\mu\text{m}$  and 2000  $\mu\text{m}$ , preferably between 80 and 1000  $\mu\text{m}$ , more preferably between 100 and 750  $\mu\text{m}$ , even more preferably between 150 and 500  $\mu\text{m}$ , still more preferably between 200 and 300  $\mu\text{m}$ , and step d) is preferably not performed.

**[0080]** In another preferred embodiment, step b) comprises or consists of shredding, slicing or milling followed by pulsed electric field treatment, step c) comprises or consists of one or more pressing cycles with optional soaking followed by filtration over a solid filter medium with mesh openings between above 10  $\mu\text{m}$  and 2000  $\mu\text{m}$ , preferably between 80 and 1000  $\mu\text{m}$ , more preferably between 100 and 750  $\mu\text{m}$ , even more preferably between 150 and 500  $\mu\text{m}$ , still more preferably between 200 and 300  $\mu\text{m}$ , followed by one or more selected from cocurrent or countercurrent extraction, static settling, dynamic settling, spiral plate centrifuging, disk stack centrifuging, decanting, screw pressing, plunger pressing, belt pressing, precoat filtration, flotation, shaker screening, hydraulic cyclone separation and hydraulic upflow classification, preferably disc stack centrifuging, and step d) is preferably not performed.

**[0081]** In still another preferred embodiment, step b) consists of milling, preferably hammer milling, step c) comprises or consists of one or more pressing cycles with optional soaking followed by filtration over a solid filter medium with mesh openings between above 10  $\mu\text{m}$  and 2000  $\mu\text{m}$ , preferably between 80 and 1000  $\mu\text{m}$ , more preferably between 100 and 750  $\mu\text{m}$ , even more preferably between 150 and 500  $\mu\text{m}$ , still more preferably between 200 and 300  $\mu\text{m}$ , and step d) is preferably not performed.

**[0082]** In embodiments, step d) is mandatory and the fine physical purification in step d) comprises or consists of microfiltration using a membrane with a pore size of between more than 0.1 and 10  $\mu\text{m}$ , preferably with a pore size of

between 0.105 and 5  $\mu\text{m}$ , more preferably with a pore size of between 0.11 and 2.5  $\mu\text{m}$ , even more preferably with a pore size of between 0.12 and 1  $\mu\text{m}$ , still more preferably with a pore size of between 0.15 - 0.4  $\mu\text{m}$ .

**[0083]** As will be appreciated by those skilled in the art, when microfiltration is used as the fine physical purification step, the clarified sugar beet juice is the permeate. Microfiltration as the fine physical purification step can advantageously be applied to remove microorganisms from the filtered sugar beet juice obtained in step c) (without removing for example valuable nutrients).

**[0084]** In a preferred embodiment, step b) comprises or consists of shredding, slicing or milling followed by pulsed electric field treatment, step c) comprises or consists of one or more pressing cycles with optional soaking followed by filtration over a solid filter medium with mesh openings between above 10  $\mu\text{m}$  and 2000  $\mu\text{m}$ , preferably between 80 and 1000  $\mu\text{m}$ , more preferably between 100 and 750  $\mu\text{m}$ , even more preferably between 150 and 500  $\mu\text{m}$ , still more preferably between 200 and 300  $\mu\text{m}$ , and step d) is mandatory and comprises or consists of microfiltration using a membrane with a pore size of between more than 0.1 and 10  $\mu\text{m}$ , preferably with a pore size of between 0.105 and 5  $\mu\text{m}$ , more preferably with a pore size of between 0.11 and 2.5  $\mu\text{m}$ , even more preferably with a pore size of between 0.12 and 1  $\mu\text{m}$ , still more preferably with a pore size of between 0.15 - 0.4  $\mu\text{m}$ .

**[0085]** In preferred embodiments, the method as defined herein is a method for the preparation of a filtered sugar beet juice, clarified sugar beet juice or sugar beet syrup characterized by between 500 and 7000 mg/kg, preferably between 800 and 5000 mg/kg, more preferably between 1000 and 3500 mg/kg of phosphate, and one or more of the following properties, wherein the concentrations are based on total dissolved dry solids weight:

- i) substantially free or free of 2,5-dimethylpyrazine;
- ii) substantially free or free of 2-ethyl-3-methylpyrazine;
- iii) substantially free or free of 2,3,5-trimethylpyrazine;
- iv) less than 500 mg/kg, preferably less than 450 mg/kg, more preferably less than 400 mg/kg, even more preferably less than 350 mg/kg of sulfate;
- v) less than 600 mg/kg, preferably less than 500 mg/kg, more preferably less than 400 mg/kg, even more preferably less than 370 mg/kg of pyrrolidone carbonic acid;
- vi) between 1000 and 7000 mg/kg, preferably between 1500 and 5000 mg/kg, more preferably between 2000 and 4000 mg/kg, even more preferably between 2500 and 3500 mg/kg of oxalate; and
- vii) more than 500 mg/kg, preferably more than 650 mg/kg, more preferably more than 850 mg/kg, even more preferably more than 1000 mg/kg, of the combined amount of histidine and glutamine.

**[0086]** In a preferred embodiment, the method as defined herein is a method for the preparation of a filtered sugar beet juice, clarified sugar beet juice or sugar beet syrup characterized by between 500 and 7000 mg/kg, preferably between 800 and 5000 mg/kg, more preferably between 1000 and 3500 mg/kg of phosphate, and:

- a combination of i), ii) and iii);
- a combination of i) - iv);
- a combination of i) - v);
- a combination of i) - vi);
- a combination of i) - vii); or
- a combination of iv) - vii).

**[0087]** The term '*substantially free*' relating to liquids or juices in the context of the current invention preferably means 'present' (such as qualitatively detectable) but in a concentration less than 100  $\mu\text{g/kg}$ , preferably less than 10  $\mu\text{g/kg}$ , more preferably less than 1  $\mu\text{g/kg}$ , even more preferably less than 0.1  $\mu\text{g/kg}$ , based on total dissolved dry solids weight.

**[0088]** The wording '*substantially free or free of pyrazines*' as used herein can also be construed as '*substantially free or free of 2,5-dimethylpyrazine, 2-ethyl-3-methylpyrazine and 2,3,5-trimethylpyrazine*'.

**[0089]** In a second aspect, the invention concerns the filtered sugar beet juice, clarified sugar beet juice and sugar beet syrup obtainable by the methods as defined herein, preferably the sugar beet syrup obtainable by the methods as defined herein.

**[0090]** In preferred embodiments, the method as defined herein further comprises subjecting the filtered sugar beet juice of step c), the clarified sugar beet juice of step d) or the sugar beet syrup obtained in step e) to a further concentration step f) resulting in crystallized sugar and sugar beet molasses.

**[0091]** In very preferred embodiments, the method as defined herein comprises subjecting the sugar beet syrup obtained in step e) to a further concentration step f) resulting in crystallized sugar and sugar beet molasses.

**[0092]** Examples of concentration step f), resulting in supersaturation and crystallization, encompass (I) evaporative crystallization, wherein supersaturation and crystallization are realized by evaporation of water, (II) direct cooling crystallization, wherein supersaturation and crystallization are realized by cooling the sugar beet syrup using heat exchangers,

(III) flash cooling crystallization, wherein the sugar beet syrup is subjected to a pressure drop resulting in evaporation of water and a corresponding temperature drop of the sugar beet syrup causing supersaturation and crystallization, and (IV) combinations thereof. Crystallization may be facilitated by adding sugar seed crystals to the concentrated sugar beet syrup.

**[0093]** The temperature in step f) is preferably between 40 and 130 °C, more preferably between 45 and 112 °C, even more preferably between 50 and 105 °C.

**[0094]** Crystallized sugar and sugar beet molasses can be separated using, for example, a centrifuge.

**[0095]** In a preferred embodiment, no alkalization agent is employed in step (f).

**[0096]** In another preferred embodiment, the pH in steps (a) to (e) in the process as defined herein is in the range of 0.5 - 7, preferably in the range of 3.5 - 7, more preferably in the range of 4.5 - 7.

**[0097]** In still another preferred embodiment, the process as defined herein does not encompass a demineralization or softening step.

**[0098]** In yet another preferred embodiment, the process as defined herein does not comprise a chemical purification step. A chemical purification step in the context of the present invention is a purification step wherein chemicals that are capable of reacting or interacting with the sugar beet material are added. As will be appreciated by those skilled in the art, this does not encompass water, such as plain tap water or condensation water.

**[0099]** In preferred embodiments, the method as defined herein is a method for the preparation of a crystallized sugar and sugar beet molasses, wherein the sugar beet molasses is characterized by between 100 and 50000 mg/kg, preferably between 1000 and 40000 mg/kg, more preferably between 5000 and 30000 mg/kg, still more preferably between 10000 and 25000 mg/kg of phosphate, and one or more of the following properties, wherein the concentrations are based on total dissolved dry solids weight:

i) substantially free or free of 2,5-dimethylpyrazine;

ii) substantially free or free of 2-ethyl-3-methylpyrazine;

iii) substantially free or free of 2,3,5-trimethylpyrazine;

iv) less than 11000 mg/kg, preferably less than 9000 mg/kg, more preferably less than 7000 mg/kg, even more preferably less than 5000 mg/kg of sulfate;

v) less than 8000 mg/kg, preferably less than 7500 mg/kg, more preferably less than 7000 mg/kg, even more preferably less than 6500 mg/kg, still more preferably less than 6000 mg/kg of pyrrolidone carbonic acid;

vi) between 1000 and 100000 mg/kg, preferably between 3000 and 80000 mg/kg, more preferably between 9000 and 70000 mg/kg, even more preferably between 12000 and 60000 mg/kg, still more preferably between 15000 and 50000 mg/kg of oxalate; and

vii) more than 300 mg/kg, preferably more than 600 mg/kg, more preferably more than 900 mg/kg, even more preferably more than 1200 mg/kg, of the combined amount of histidine and glutamine.

**[0100]** In a preferred embodiment, the method as defined herein is a method for the preparation of a crystallized sugar and sugar beet molasses, wherein the sugar beet molasses is characterized by between 100 and 50000 mg/kg, preferably between 1000 and 40000 mg/kg, more preferably between 5000 and 30000 mg/kg, still more preferably between 10000 and 25000 mg/kg of phosphate, and:

- a combination of i), ii) and iii);
- a combination of i) - iv);
- a combination of i) - v);
- a combination of i) - vi);
- a combination of i) - vii); or
- a combination of iv) - vii).

**[0101]** In preferred embodiments, the method as defined herein is a method for the preparation of a crystallized sugar and sugar beet molasses characterized by the following crystallized sugar properties, wherein the concentrations are based on total dry solids weight:

i) substantially free or free of 2,5-dimethylpyrazine;

ii) substantially free or free of 2-ethyl-3-methylpyrazine;

iii) substantially free or free of 2,3,5-trimethylpyrazine; or

iv) a combination of i), ii) and iii).

**[0102]** The term '*substantially free*' relating to crystallized sugar in the context of the current invention preferably means 'present' (such as qualitatively detectable) but in a concentration less than 100 µg/kg, preferably less than 10 µg/kg,

more preferably less than 1 µg/kg, even more preferably less than 0.1 µg/kg, based on total dry solids weight.

**[0103]** In a third aspect, the invention concerns the crystallized sugar and sugar beet molasses obtainable by the methods as defined herein.

**[0104]** A fourth aspect of the invention concerns filtered sugar beet juice, clarified sugar beet juice or sugar beet syrup characterized by between 500 and 7000 mg/kg, preferably between 800 and 5000 mg/kg, more preferably between 1000 and 3500 mg/kg of phosphate, and one or more of the following properties, wherein the concentrations are based on total dissolved dry solids weight:

- i) substantially free or free of 2,5-dimethylpyrazine;
- ii) substantially free or free of 2-ethyl-3-methylpyrazine;
- iii) substantially free or free of 2,3,5-trimethylpyrazine;
- iv) less than 500 mg/kg, preferably less than 450 mg/kg, more preferably less than 400 mg/kg, even more preferably less than 350 mg/kg of sulfate;
- v) less than 600 mg/kg, preferably less than 500 mg/kg, more preferably less than 400 mg/kg, even more preferably less than 370 mg/kg of pyrrolidone carbonic acid;
- vi) between 1000 and 7000 mg/kg, preferably between 1500 and 5000 mg/kg, more preferably between 2000 and 4000 mg/kg, even more preferably between 2500 and 3500 mg/kg of oxalate; and
- vii) more than 500 mg/kg, preferably more than 650 mg/kg, more preferably more than 850 mg/kg, even more preferably more than 1000 mg/kg, of the combined amount of histidine and glutamine.

**[0105]** In a preferred embodiment, the filtered sugar beet juice, clarified sugar beet juice or sugar beet syrup is characterized by between 500 and 7000 mg/kg, preferably between 800 and 5000 mg/kg, more preferably between 1000 and 3500 mg/kg of phosphate, and:

- a combination of i), ii) and iii);
- a combination of i) - iv);
- a combination of i) - v);
- a combination of i) - vi);
- a combination of i) - vii); or
- a combination of iv) - vii).

**[0106]** It has surprisingly been found that the filtered beet juice, the clarified beet juice and the beet syrup according to the invention or obtainable by the methods according to the invention are less colored when compared to the equivalent products (so-called thin juice and thick juice) obtained through a conventional method comprising extraction at a temperature of about 72-74°C and raw juice purification steps comprising liming, carbonation, filtration and softening. In embodiments there is thus provided filtered beet juice, clarified beet juice or beet syrup according to the invention or filtered beet juice, clarified beet juice or beet syrup obtainable by the methods according to the invention wherein the colour is in the range of 100-20000 IU, preferably in the range of 100-10000 IU, more preferably in the range of 100-6000 IU, even more preferably in the range of 100-2000 IU, still more preferably in the range of 100-1000 IU, yet more preferably in the range of 100-500 IU, as determined according to ICUMSA GS1/3-7 (2011), with pH correction.

**[0107]** In a fifth aspect of the invention, sugar beet molasses is provided, characterized by between 100 and 50000 mg/kg, preferably between 1000 and 40000 mg/kg, more preferably between 5000 and 30000 mg/kg, still more preferably between 10000 and 25000 mg/kg of phosphate, and one or more of the following properties, wherein the concentrations are based on total dissolved dry solids weight:

- i) substantially free or free of 2,5-dimethylpyrazine;
- ii) substantially free or free of 2-ethyl-3-methylpyrazine;
- iii) substantially free or free of 2,3,5-trimethylpyrazine;
- iv) less than 11000 mg/kg, preferably less than 9000 mg/kg, more preferably less than 7000 mg/kg, even more preferably less than 5000 mg/kg of sulfate;
- v) less than 8000 mg/kg, preferably less than 7500 mg/kg, more preferably less than 7000 mg/kg, even more preferably less than 6500 mg/kg, still more preferably less than 6000 mg/kg of pyrrolidone carbonic acid;
- vi) between 1000 and 100000 mg/kg, preferably between 3000 and 80000 mg/kg, more preferably between 9000 and 70000 mg/kg, even more preferably between 12000 and 60000 mg/kg, still more preferably between 15000 and 50000 mg/kg of oxalate; and
- vii) more than 300 mg/kg, preferably more than 600 mg/kg, more preferably more than 900 mg/kg, even more preferably more than 1200 mg/kg, of the combined amount of histidine and glutamine.

[0108] In a preferred embodiment, the sugar beet molasses is characterized by between 100 and 50000 mg/kg, preferably between 1000 and 40000 mg/kg, more preferably between 5000 and 30000 mg/kg, still more preferably between 10000 and 25000 mg/kg of phosphate, and:

- 5 • a combination of i), ii) and iii);
- a combination of i) - iv);
- a combination of i) - v);
- a combination of i) - vi);
- a combination of i) - vii); or
- 10 • a combination of iv) - vii).

[0109] In a sixth aspect of the invention, crystallized sugar characterized by the following properties, wherein the concentrations are based on total dry solids weight, is provided:

- 15 i) substantially free or free of 2,5-dimethylpyrazine;
- ii) substantially free or free of 2-ethyl-3-methylpyrazine;
- iii) substantially free or free of 2,3,5-trimethylpyrazine; or
- iv) a combination of i), ii) and iii).

20 [0110] Preferred embodiments concern food products for human consumption comprising the sugar beet syrup, sugar beet molasses or crystallized sugar as defined herein or obtainable by the methods as defined herein. Non-limiting examples of said food products are cereal bars, soft drink, sauces, confectionery, such as gums, liquorice, hard candy, bakery products, such as muffins and cookies, and dairy products such as ice cream.

[0111] Another embodiment concerns feed or pet food comprising the sugar beet syrup, sugar beet molasses or crystallized sugar as defined herein or obtainable by the methods as defined herein.

[0112] Another embodiment concerns the use of sugar beet syrup or sugar beet molasses as defined herein or obtainable by the methods as defined herein in fermentation processes for producing non-food or food products.

[0113] The sugar beet syrup and sugar beet molasses as defined herein or obtainable by the methods as defined herein can also be used as such for human consumption or as feed or pet food.

30 [0114] Accordingly, a seventh aspect of the invention concerns the use of the sugar beet syrup or sugar beet molasses as defined herein or the sugar beet syrup or sugar beet molasses obtainable by the processes as defined herein as a food product for human consumption or as a sweetener in food products for human consumption, such as in liquorice, cereal bars and bakery products.

[0115] Obviously, the crystallized sugar as defined herein or obtainable by the methods as defined herein can also be used as a food product for human consumption or as a sweetener in food products for human consumption.

[0116] Thus, the invention has been described by reference to certain embodiments discussed above. It will be recognized that these embodiments are susceptible to various modifications and alternative forms well known to those of skill in the art.

40 [0117] Furthermore, for a proper understanding of this document and its claims, it is to be understood that the verb 'to comprise' and its conjugations are used in its non-limiting sense to mean that items following the word are included, but items not specifically mentioned are not excluded. In addition, reference to an element by the indefinite article 'a' or 'an' does not exclude the possibility that more than one of the element is present, unless the context clearly requires that there be one and only one of the elements. The indefinite article 'a' or 'an' thus usually means 'at least one'.

## 45 Examples

### Example 1: production of PEF-raw beet juice

50 [0118] 1000 kg of sugar beets were obtained from Suiker Unie (Dinteloord, NL) and washed in a flotation washer to remove sand and pebbles. The sugar beets were sliced into cossettes of about 3.5 mm thickness using a cossette slicer with standard AB knife blocks. The cossettes were exposed to a pulsed electric field using a Dil, Elcrack HVP 30, treatment bath TB 140 device, with the following parameters: field strength 1,4 kV/cm, pulse time 20  $\mu$ s, frequency 200 Hz, temperature 25 °C, and conductivity of treatment medium 400  $\mu$ S/cm.

55 [0119] Raw beet juice, herein referred to as **PEF-raw beet juice** was recovered from the PEF treated cossettes by performing 5 cycles of repetitive pressing and soaking using a Babbini twin screw pulp press B20B, equipped with a 1 mm mesh and using a 1:1 ratio of press juice:water for soaking.

**Example 2: production of acid-raw beet juice**

[0120] 700 kg of sugar beets were obtained from Suiker Unie (Dinteloord, NL) and washed in a flotation washer to remove sand and pebbles. The sugar beets were sliced into cossettes of about 5 mm thickness using a vegetable slicer (FAM ILC.2). The cossettes were acidified using a fermentation inoculum, made from naturally acidified sugar beet juice. Cossettes were mixed with water of 25 °C and inoculum in a ratio 1:0.75:0.25 and held for 20 hours.

[0121] Raw beet juice having pH 4.0, herein referred to as **acid-raw beet juice** was recovered from the acid treated cossettes by performing 2 cycles of repetitive pressing and soaking using a Babbini twin screw pulp press B20B, equipped with a 1-2 mm mesh and using a 1:2 ratio of press pulp:water for soaking during 30 minutes.

**Example 3: production of freeze-thaw-treated-raw beet juice**

[0122] 700 kg of sugar beets were obtained from Suiker Unie (Dinteloord, NL) and washed in a flotation washer to remove sand and pebbles. The sugar beets were stored frozen at -20°C for 1 week and thawed under ambient conditions prior to slicing into cossettes of about 5 mm thickness using a vegetable slicer (FAM ILC.2).

[0123] Raw beet juice, herein referred to as **freeze-thaw-treated-raw beet juice 1** was recovered from the freeze-thaw treated beets by performing 2 cycles of repetitive pressing and soaking using a screw press equipped with an 1 mm mesh and using a 1:2 ratio of press pulp:water for soaking during 30 minutes.

[0124] From another part of the cossettes, raw beet juice, herein referred to as **freeze-thaw-treated-raw beet juice 2** was recovered from the freeze-thaw treated beets by performing a single pressing step using a Babbini twin screw pulp press B20B, equipped with a 1 mm mesh.

**Example 4: production of milled-raw beet juice**

[0125] 10.000 kg of sugar beets were obtained from Suiker Unie (Dinteloord, NL) and washed in a flotation washer to remove sand and pebbles. The sugar beets were milled into a mush using a hammer mill (Engl SM60), rotating at 3000 rpm and equipped with a screen with 3 mm mesh size.

[0126] Raw beet juice, herein referred to as **milled-raw beet juice** was recovered from the mush using a disc bowl decanter (Pieralisi BABY 2; 3450 rpm, 40% torque).

**Example 5: production of milled-pressed-raw beet juice**

[0127] 150 kg of sugar beets were obtained from Suiker Unie (Dinteloord, NL) and washed in a flotation washer to remove sand and pebbles. The sugar beets were milled into a mush using a hammer mill (Engl, SM60), rotating at 3000 rpm and equipped with a screen with 3 mm mesh size.

[0128] Raw beet juice, herein referred to as **milled-pressed-raw beet juice** was recovered from the mush using a basket press (Hafico, HP2H hydraulic press), operating at 16 bar with a residence time of 10 minutes. Identical results were obtained when the basket press was replaced by a screw compression filter (Smicon MAS; 5 bar, 150 µm screen).

**Example 6a: production of beet syrup**

[0129] The PEF-raw beet juice from Example 1 was passed through a 250 micron mesh screen (Reko, sieve bend 500 TS) and the filtrate was collected. A part of the resulting filtered beet juice, herein referred to as **PEF-filtered beet juice**, was used to produce a syrup through evaporation in a Buchi thin film evaporator, R 220 SE, operated at 70 °C and 200 mbar to yield **PEF-beet syrup 1**.

**Example 6b: production of beet syrup**

[0130] The PEF-raw beet juice from Example 1 was passed through a 250 micron mesh screen (Reko, sieve bend 500 TS) and the filtrate was collected. A part of the resulting filtered beet juice, herein referred to as **PEF-filtered beet juice**, was subjected to ultrafiltration using a 15 kDa Molecular Weight Cut Off membrane (Tami 15 kDa, ceramic membrane, 23 channels, hydraulic diameter 3.5 mm, length 1178 mm, surface 0.35 m<sup>2</sup>) and the permeate was collected to yield clarified beet juice, herein referred to as **PEF-clarified beet juice**.

[0131] **PEF-clarified beet juice** was evaporated in a Buchi thin film evaporator, R 220 SE, operated at 70 °C and 200 mbar to yield and **PEF-beet syrup 2**.

**Example 7a: production of crystallized sugar and molasses**

[0132] Crystallized sugar and molasses were produced from **PEF-beet syrup 1** by performing evaporative crystallization to yield **PEF-crystal sugar 1** and **PEF-molasses 1**. The evaporative crystallizer used is of the type described in K. Schlumbach et al., Sugar Industry, 140(8) (2015), pp 500-507.

[0133] The combined process of Examples 1, 6a and 7a is depicted in Figure 4, wherein (4a) represents **PEF-raw beet juice**, (4b) **PEF-filtered beet juice**, (4c) **PEF-beet syrup 1**, (4d) **PEF-crystal sugar 1** and (4e) **PEF-molasses 1**.

**Example 7b: production of crystallized sugar and molasses**

[0134] Crystallized sugar and molasses were produced from **PEF-beet syrup 2** by performing evaporative crystallization to yield **PEF-crystal sugar 2** and **PEF-molasses 2**. The evaporative crystallizer used is of the type described in K. Schlumbach et al., Sugar Industry, 140(8) (2015), pp 500-507.

[0135] The combined process of Examples 1, 6b and 7b is depicted in Figure 3, wherein (3a) represents **PEF-raw beet juice**, (3b) **PEF-filtered beet juice**, (3c) **PEF-clarified beet juice**, (3d) **PEF-beet syrup 2**, (3e) **PEF-crystal sugar 2** and (4f) **PEF-molasses 2**.

**Example 8: Analysis of the products of Example 6b**

[0136] The **PEF-clarified beet juice** and **PEF-beet syrup 2** obtained in Example 6b were analysed and compared to analysis results of their equivalent products produced using a conventional extraction/purification process for sugar beets. The conventional extraction/purification process comprising extraction at a temperature of about 72-74°C and raw juice purification steps comprising liming, carbonation, filtration and softening is depicted in Figure 7, wherein (7a) represents conventional raw beet juice, (7b) conventional thin beet juice, (3c) conventional thick beet juice, (7d) conventional crystal sugar and (7e) conventional molasses.

[0137] Conventional thin beet juice was obtained from Suiker Unie (Netherlands, 2017/2018 campaign). Traditional thick juice was obtained from Suiker Unie (Netherlands) with article number 204.

[0138] Several analysis methods were used to specify and or quantify the ingredients in PEF-clarified beet juice, conventional thin juice, PEF-beet syrup 2 and conventional thick juice (see Table 1). The amount of the ingredients is expressed in terms of mg per kg of dissolved dry matter. Raw juice, for example, comprises dissolved compounds, such as sucrose and amino acids, and small amounts of non-dissolved particulate matter resulting after extraction of sugar beets. The amount of the ingredients is expressed in only based on the dry matter that is dissolved in the juice. The analysis methods (1) to (7) are as follows.

(1) GC/MS analysis using a Thermo TraceGC Ultra gas chromatograph equipped with a Stabilwax column (Restek (art.nr. 10642), 60 m, 0.32 mm ID, 0.5 µm df) using headspace-injection after addition of NaCl to the sample followed by mass spectrometry (MS, Thermo Trace DSQ) detection.

(2) Dilution and, when necessary, filtration of sample followed by high performance ion chromatography (HPIC, Thermo Scientific, Dionex Integrion) using a Dionex IonPac AS11-HC-4µm column (Thermo Scientific (art.nr. 078035) 2 x 250 mm) and conductivity detection (Thermo Scientific, art.nr. 22153-60036).

(3) Dilution and filtration of sample followed by high performance ion chromatography (HPIC, Thermo Scientific, Dionex Integrion) using a Aminex HPX-87H column (Biorad (art.nr. 125-0140) 300 x 7.8 mm) and conductivity detection (Thermo Scientific, art.nr. 22153-60036).

(4) HPLC-UV/FLU in accordance with EP2.2.56 and USP <1052>.

(5) Kjeldahl analysis using Buchi KjelMaster K-375.

(6) UV-VIS spectra were recorded using a Hach Lange DR 5000 spectrometer.

(7) Dry matter content was determined by weighing the sample before and after heating at 80°C for 18 hours and at 105°C for 2 hours.

EP 3 783 115 A1

Table 1

| Analysis method | Compound                   | PEF-clarified beet juice (mg/kg dissolved dry matter) | Conventional thin juice (mg/kg dissolved dry matter) |  | PEF-beet syrup 2 (mg/kg dissolved dry matter) | Conventional thick juice (mg/kg dissolved dry matter) |
|-----------------|----------------------------|-------------------------------------------------------|------------------------------------------------------|--|-----------------------------------------------|-------------------------------------------------------|
| 1               | Dimethyl sulfide           | Present                                               | Present                                              |  | Present                                       | Not present                                           |
| 1               | Ethyl acetate              | Present                                               | Not present                                          |  | Not measured                                  | Not measured                                          |
| 1               | Methanol                   | Present                                               | Present                                              |  | Not measured                                  | Not measured                                          |
| 1               | Ethanol                    | Present                                               | Present                                              |  | Present                                       | present                                               |
| 1               | Diacetyl                   | Not present                                           | Present                                              |  | Not present                                   | present                                               |
| 1               | Isobutanol                 | Present                                               | Not present                                          |  | Not measured                                  | Not measured                                          |
| 1               | Isoamylalcohol             | Present                                               | Not present                                          |  | Not measured                                  | Not measured                                          |
| 1               | 2,5-dimethylpyrazine       | Not present                                           | Present                                              |  | Not present                                   | Present                                               |
| 1               | 2-ethyl-3-methylpyrazine   | Not present                                           | Present                                              |  | Not present                                   | Present                                               |
| 1               | 2,3,5-trimethylpyrazine    | Not present                                           | Present                                              |  | Not present                                   | Present                                               |
| 1               | Benzaldehyde               | Not present                                           | Present                                              |  | Not measured                                  | Not measured                                          |
| 1               | acetone                    | Not measured                                          | Not measured                                         |  | Present                                       | Not present                                           |
| 1               | Dimethyl disulfide         | Not measured                                          | Not measured                                         |  | Not present                                   | present                                               |
| 1               | Acetic acid                | Not measured                                          | Not measured                                         |  | Present                                       | Not present                                           |
| 2               | Chloride                   | 669                                                   | 524                                                  |  | 649                                           | 669                                                   |
| 2               | Bromide                    | <20                                                   | <20                                                  |  | <100                                          | <20                                                   |
| 2               | Nitrate                    | 765                                                   | 620                                                  |  | 796                                           | 948                                                   |
| 2               | Phosphate                  | 2242                                                  | 212                                                  |  | 2360                                          | <20                                                   |
| 2               | Malate                     | 647                                                   | 671                                                  |  | 619                                           | 474                                                   |
| 2               | Sulfate                    | 217                                                   | 1843                                                 |  | 192                                           | 1674                                                  |
| 2               | Oxalate                    | 1974                                                  | <20                                                  |  | 944                                           | 93                                                    |
| 2               | Nitrite                    | <20                                                   | <20                                                  |  | <100                                          | 43                                                    |
| 3               | Citric acid                | 2228                                                  | 468                                                  |  | 2212                                          | 516                                                   |
| 3               | Malic acid                 | 569                                                   | 404                                                  |  | 501                                           | 586                                                   |
| 3               | Lactic acid                | 1509                                                  | 4314                                                 |  | 2507                                          | 4603                                                  |
| 3               | Formic acid                | <50                                                   | 338                                                  |  | <200                                          | 460                                                   |
| 3               | Acetic acid                | 1384                                                  | 882                                                  |  | 1106                                          | 1172                                                  |
| 3               | Pyrrolidonecarboxylic acid | <50                                                   | 1745                                                 |  | 339                                           | 2789                                                  |
| 3               | Propionic acid             | <50                                                   | <50                                                  |  | <200                                          | <200                                                  |
| 3               | Butyric acid               | <50                                                   | <50                                                  |  | <200                                          | <200                                                  |
| 4               | Aspartic acid              | 313                                                   | 476                                                  |  | 441                                           | 603                                                   |
| 4               | Threonine                  | 72                                                    | 100                                                  |  | 114                                           | 130                                                   |



(continued)

| Analysis method | Compound                               | PEF-clarified beet juice (mg/kg dissolved dry matter) | Conventional thin juice (mg/kg dissolved dry matter) | PEF-beet syrup 2 (mg/kg dissolved dry matter) | Conventional thick juice (mg/kg dissolved dry matter) |
|-----------------|----------------------------------------|-------------------------------------------------------|------------------------------------------------------|-----------------------------------------------|-------------------------------------------------------|
| 4               | Serine                                 | 96                                                    | 202                                                  | 242                                           | 290                                                   |
| 4               | Asparagine                             | 219                                                   | 329                                                  | 364                                           | 312                                                   |
| 4               | Glutamic acid                          | 550                                                   | 651                                                  | 608                                           | 675                                                   |
| 4               | Glutamine                              | 1135                                                  | 382                                                  | 1888                                          | 21                                                    |
| 4               | Cysteine                               | Not measured                                          | Not measured                                         | Not measured                                  | Not measured                                          |
| 4               | Proline                                | Not measured                                          | 109                                                  | 96                                            | 126                                                   |
| 4               | Glycine                                | Not measured                                          | 76                                                   | 21                                            | 124                                                   |
| 4               | Alanine                                | 147                                                   | 322                                                  | 181                                           | 296                                                   |
| 4               | Valine                                 | 103                                                   | 186                                                  | 218                                           | 240                                                   |
| 4               | Cysteine                               | Not measured                                          | Not measured                                         | Not measured                                  | Not measured                                          |
| 4               | Methionine                             | Not measured                                          | Not measured                                         | 15                                            | 25                                                    |
| 4               | Isoleucine                             | Not measured                                          | 237                                                  | 15                                            | 291                                                   |
| 4               | Leucine                                | Not measured                                          | 227                                                  | 139                                           | 254                                                   |
| 4               | Tyrosine                               | Not measured                                          | 365                                                  | 32                                            | 409                                                   |
| 4               | Phenylalanine                          | Not measured                                          | 57                                                   | 34                                            | 70                                                    |
| 4               | Gamma-Aminobutyric acid                | 874                                                   | 810                                                  | 836                                           | 614                                                   |
| 4               | Ethanolamine                           | Not measured                                          | Not measured                                         | 43                                            | 18                                                    |
| 4               | Lysine                                 | N.D.                                                  | 55                                                   | 21                                            | 63                                                    |
| 4               | 1-Methylhistidine                      | Not measured                                          | Not measured                                         | 29                                            | 64                                                    |
| 4               | Histidine                              | N.D.                                                  | 41                                                   | 46                                            | 15                                                    |
| 4               | Arginine                               | N.D.                                                  | 76                                                   | 106                                           | 52                                                    |
| 5               | Nitrogen content (wt. % of dry matter) | 0.205                                                 | 0.31                                                 | 0.255%                                        | Not measured                                          |
| 6               | UV absorption spectrum                 | Not measured                                          | Not measured                                         | See Figure 1                                  | See Figure 1                                          |
| 6               | Visible light absorption spectrum      | Not measured                                          | Not measured                                         | See Figure 2                                  | See Figure 2                                          |
| 7               | Dry matter content (wt.%)              | 8,64                                                  | 17.0                                                 | 67,8                                          | 71,7                                                  |

**Example 9: production of beet syrup using PEF and ultrafiltration as fine physical purification step**

**[0139]** Sugar beets were obtained from Suiker Unie, Dinteloord, Netherlands. The sugar beets were washed in a flotation washer to remove sand and pebbles and were reduced in size by shredding (Smicon, MD8). The resulting cossettes were exposed to a pulsed electric field using a Dil, Elcrack HVP 30, treatment bath TB 140 device, with the following parameters: field strength 1 kV/cm, conductivity treatment water 1700  $\mu$ S/cm water, temperature treatment water 25 °C, and 0.04 m/s belt speed.

**[0140]** **Raw beet juice 3** was recovered from the PEF treated shreds by performing pressing using a Babbini twin

screw pulp press B20B, equipped with an 1 mm mesh, operating at a screw speed of 0.8 rpm.

[0141] The raw beet juice 3 was passed through a 250 micron mesh screen (Reko, sieve bend 500 TS) and the filtrate was collected.

[0142] The resulting **filtered beet juice 3** was subjected to ultrafiltration (Tami 15 kDa, ceramic membrane, 23 channels, hydraulic diameter 3.5 mm, length 1178 mm, surface 0.35 m<sup>2</sup>) and the filtrate was collected to yield **clarified beet juice 3**.

[0143] Clarified beet juice 3 was evaporated in a Buchi thin film evaporator, R 220 SE, operated at a temperature of 65 °C and a vacuum of 34 mbar, to obtain **beet syrup 3**.

[0144] The process of Example 9 is depicted in Figure 3, wherein (3a) represents **raw beet juice 3**, (3b) **filtered beet juice 3**, (3c) **clarified beet juice 3**, and (3d) **beet syrup 3**. Beet syrup 3 can be subjected to crystallization, by for example evaporate concentration, to result in (3e) **molasses 3** and (3f) **crystal sugar 3**.

#### **Example 10: production of beet syrup using PEF without a fine physical purification step**

[0145] Sugar beets were obtained from Suiker Unie, Dinteloord, Netherlands. The sugar beets were washed in a flotation washer to remove sand and pebbles and were reduced in size by shredding (Smicon, MD8). The resulting shreds were exposed to a pulsed electric field using a Dil, Elcrack HVP 30, treatment bath TB 140 device, with the following parameters: field strength 1 kV/cm, conductivity treatment water 1700 µS/cm water, temperature treatment water 25 °C, and 0.04 m/s belt speed.

[0146] **Raw beet juice 4** was recovered from the PEF treated cossettes by performing pressing using a Babbini twin screw pulp press B20B, equipped with an 1 mm mesh, operating at a screw speed of 0.8 rpm.

[0147] The raw beet juice 4 was passed through a 250 micron mesh screen (Reko, sieve bend 500 TS) and the filtrate was collected to obtain **filtered beet juice 4**.

[0148] The filtered beet juice 4 was evaporated in a Buchi thin film evaporator, R 220 SE, operated at a temperature of 65 °C and a vacuum of 34 mbar, to obtain **beet syrup 4**.

[0149] The process of Example 10 is depicted in Figure 4, wherein (4a) represents **raw beet juice 4**, (4b) **filtered beet juice 4**, and (4c) **beet syrup 4**. Beet syrup 4 can be subjected to crystallization, by for example evaporate concentration, to result in (4d) **molasses 4** and (4e) **crystal sugar 4**.

#### **Example 11: production of beet syrup using PEF without a fine physical purification step**

[0150] Sugar beets were obtained from Suiker Unie, Dinteloord, Netherlands. The sugar beets were washed in a flotation washer to remove sand and pebbles and were reduced in size by shredding (Smicon, MD8). The resulting cossettes were exposed to a pulsed electric field using a Dil, Elcrack HVP 30, bath TB 140 device, with the following parameters: field strength 1 kV/cm, conductivity treatment water 1700 µS/cm water, temperature treatment water 25 °C, and 0.04 m/s belt speed.

[0151] **Raw beet juice 5** was recovered from the PEF treated cossettes by performing pressing using a Babbini twin screw pulp press B20B, equipped with an 1 mm mesh, operating at a screw speed of 0.8 rpm.

[0152] The raw beet juice 5 was passed through a 250 micron mesh screen (Reko, sieve bend 500 TS) and the filtrate was collected.

[0153] The resulting filtered beet juice was subjected to disc stack centrifuging in an Alfa Laval, Clara 20 centrifuge, operating at 250 l/h, 10500 g, 9010 rpm, 24 °C, counter pressure 2 bar, and the filtrate was collected to yield **filtered beet juice 5**.

[0154] Filtered beet juice 5 was evaporated in a Buchi thin film evaporator, R 220 SE, operated at a temperature of 65 °C and a vacuum of 34 mbar, to obtain **beet syrup 5**.

[0155] The process of Example 11 is depicted in Figure 5, wherein (5a) represents **raw beet juice 5**, (5b) **filtered beet juice 5**, and (5c) **beet syrup 5**. Beet syrup 5 can be subjected to crystallization, by for example evaporate concentration, to result in (5d) **molasses 5** and (5e) **crystal sugar 5**.

#### **Example 12: production of beet syrup using hammer milling without a fine physical purification step**

[0156] Sugar beets were obtained from Suiker Unie, Dinteloord, Netherlands. The sugar beets were washed in a flotation washer to remove sand and pebbles and were milled into a mush using a hammer mill (Engl, SM60), rotating at 3000 rpm and equipped with a screen with 3 mm mesh size.

[0157] **Raw beet juice 6** was recovered from the mush using a basket press (Hafico, HP2H hydraulic press), operating at 16 bar with a residence time of 10 minutes.

[0158] The raw beet juice 6 was passed through a 250 micron mesh screen (Reko, sieve bend 500 TS) and the filtrate was collected to obtain **filtered beet juice 6**.

[0159] The filtered beet juice 6 was evaporated in a Buchi thin film evaporator, R 220 SE, operated at a temperature

of 65 °C and a vacuum of 34 mbar, to obtain **beet syrup 6**.

**[0160]** The process of Example 12 is depicted in Figure 6, wherein (6a) represents **raw beet juice 6**, (6b) **filtered beet juice 6**, and (6c) **beet syrup 6**. Beet syrup 6 can be subjected to crystallization by for example evaporate concentration to result in (6d) **molasses 6** and (6e) **crystal sugar 6**.

#### ***Example 13: Analysis of the products of Examples 9-12***

**[0161]** Several analysis methods were used to specify and or quantify the ingredients in **conventional raw juice**, **conventional thin juice**, **conventional thick juice**, **raw beet juice 3** (=raw beet juice 4 and 5), **filtered beet juice 6**, **clarified beet juice 3**, **clarified beet juice 5**, **beet syrup 3**, **beet syrup 4**, **beet syrup 5** and **beet syrup 6** (see Table 2).

**[0162]** The conventional extraction/purification process comprising extraction at a temperature of about 72-74°C and raw juice purification steps comprising liming, carbonation, filtration and softening is depicted in Figure 7, wherein (7a) represents conventional raw beet juice, (7b) conventional thin beet juice, (3c) conventional thick beet juice, (7d) conventional crystal sugar and (7e) conventional molasses. Conventional thin beet juice was obtained from Suiker Unie (Netherlands, 2018-2019 campaign). Traditional thick juice was obtained from Suiker Unie (Netherlands 2018-2019 campaign).

**[0163]** The amount of the ingredients is expressed in terms of mg per kg of dissolved dry matter. Raw juice, for example, comprises dissolved compounds, such as sucrose and amino acids, and small amounts of non-dissolved particulate matter resulting after extraction of sugar beets. The amount of the ingredients is expressed in only based on the dry matter that is dissolved in the juice. Total dissolved solids was determined using dilution and, where necessary, filtration of the sample followed by high performance liquid chromatography (HPLC, Thermo Scientific, Dionex Ultimate 3000) using an Aminex HPX-87N column (Aminex (art.nr. 125-0143) 7.8 x 300 mm) and RI detector (ERC, art.nr. 5060.0050).

**[0164]** The analysis methods (1) to (6) are as follows.

(1) GC/MS analysis using a Thermo TraceGC Ultra gas chromatograph equipped with a Stabilwax column (Restek (art.nr. 10642), 60 m, 0.32 mm ID, 0.5 µm df) using solid-phase micro-extraction sampling with a DVB/CAR/PDMS fiber (Supelco, article number 57298-U) after addition of NaCl to the sample followed by mass spectrometry (MS, Thermo Trace DSQ) detection.

(2) Dilution and, when necessary, filtration of sample followed by high performance ion chromatography (HPIC, Thermo Scientific, Dionex Integrion) using a Dionex IonPac AS11-HC-4µm column (Thermo Scientific (art.nr. 078035) 2 x 250 mm) and conductivity detection (Thermo Scientific, art.nr. 22153-60036).

(3) Dilution and filtration of sample followed by high performance ion chromatography (HPIC, Thermo Scientific, Dionex Integrion) using a Aminex HPX-87H column (Biorad (art.nr. 125-0140) 300 x 7.8 mm) and conductivity detection (Thermo Scientific, art.nr. 22153-60036).

(4) Dilution and filtration of sample followed by derivatization using AccQ-tag Chemistry Kit (Waters, article number WAT052875). Derivatized samples were analysed by high performance liquid chromatography (HPLC) using a AccQ-tag reversed-phase column (Waters, article number WAT052885, 4 µm, 3.9 mm x 150 mm) and fluorescence detection.

(5) Dry matter content was determined by weighing the sample before and after heating at 80°C for 18 hours and at 105°C for 2 hours

(6) Dilution and, when necessary, filtration of sample followed by high performance liquid chromatography (HPLC, Thermo Scientific, Dionex Ultimate 300) using an Aminex HPX-87N column (Aminex [art. nr. 125-0143] 7.8 x 300 mm) and RI detector (ERC, art. nr. 5060.0050).

# EP 3 783 115 A1

Table 2

| Analysis method              | Compound                 | Conventional raw juice | Conventional thin juice | Conventional thick juice | Raw beet juice 3, 4 and 5 | Filtered beet juice 6 | Clarified beet juice 3 | Filtered beet juice 5 | Beet syrup 3      | Beet syrup 4      | Beet syrup 5      | Beet syrup 6      |
|------------------------------|--------------------------|------------------------|-------------------------|--------------------------|---------------------------|-----------------------|------------------------|-----------------------|-------------------|-------------------|-------------------|-------------------|
| mg/(kg dissolved dry matter) |                          |                        |                         |                          |                           |                       |                        |                       |                   |                   |                   |                   |
| 1                            | Dimethyl sulfide         | ND <sup>(a)</sup>      | ND <sup>(a)</sup>       | ND <sup>(a)</sup>        | ND <sup>(a)</sup>         | ND <sup>(a)</sup>     | ND <sup>(a)</sup>      | ND <sup>(a)</sup>     | ND <sup>(a)</sup> | ND <sup>(a)</sup> | ND <sup>(a)</sup> | ND <sup>(a)</sup> |
| 1                            | Aceton                   | ND <sup>(a)</sup>      | ND <sup>(a)</sup>       | ND <sup>(a)</sup>        | ND <sup>(a)</sup>         | ND <sup>(a)</sup>     | ND <sup>(a)</sup>      | ND <sup>(a)</sup>     | ND <sup>(a)</sup> | ND <sup>(a)</sup> | ND <sup>(a)</sup> | ND <sup>(a)</sup> |
| 1                            | Ethanol                  | X <sup>(b)</sup>       | X <sup>(b)</sup>        | X <sup>(b)</sup>         | X <sup>(b)</sup>          | X <sup>(b)</sup>      | X <sup>(b)</sup>       | X <sup>(b)</sup>      | ND <sup>(a)</sup> | X <sup>(b)</sup>  | ND <sup>(a)</sup> | ND <sup>(a)</sup> |
| 1                            | Methanol                 | X <sup>(b)</sup>       | X <sup>(b)</sup>        | X <sup>(b)</sup>         | ND <sup>(a)</sup>         | ND <sup>(a)</sup>     | ND <sup>(a)</sup>      | ND <sup>(a)</sup>     | ND <sup>(a)</sup> | X <sup>(b)</sup>  | ND <sup>(a)</sup> | ND <sup>(a)</sup> |
| 1                            | Diacetyl                 | ND <sup>(a)</sup>      | ND <sup>(a)</sup>       | ND <sup>(a)</sup>        | ND <sup>(a)</sup>         | ND <sup>(a)</sup>     | ND <sup>(a)</sup>      | ND <sup>(a)</sup>     | ND <sup>(a)</sup> | ND <sup>(a)</sup> | ND <sup>(a)</sup> | ND <sup>(a)</sup> |
| 1                            | Dimethyl disulfide       | ND <sup>(a)</sup>      | X <sup>(b)</sup>        | ND <sup>(a)</sup>        | ND <sup>(a)</sup>         | ND <sup>(a)</sup>     | Y <sup>(c)</sup>       | Y <sup>(c)</sup>      | X <sup>(b)</sup>  | ND <sup>(a)</sup> | ND <sup>(a)</sup> | ND <sup>(a)</sup> |
| 1                            | 2,5-dimethylpyrazine     | X <sup>(b)</sup>       | X <sup>(b)</sup>        | X <sup>(b)</sup>         | Y <sup>(c)</sup>          | Y <sup>(c)</sup>      | Y <sup>(c)</sup>       | Y <sup>(c)</sup>      | Y <sup>(c)</sup>  | Y <sup>(c)</sup>  | Y <sup>(c)</sup>  | Y <sup>(c)</sup>  |
| 1                            | 2-ethyl-3-methylpyrazine | X <sup>(b)</sup>       | X <sup>(b)</sup>        | X <sup>(b)</sup>         | Y <sup>(c)</sup>          | Y <sup>(c)</sup>      | Y <sup>(c)</sup>       | Y <sup>(c)</sup>      | Y <sup>(c)</sup>  | Y <sup>(c)</sup>  | Y <sup>(c)</sup>  | Y <sup>(c)</sup>  |
| 1                            | 2,3,5-trimethylpyrazine  | X <sup>(b)</sup>       | X <sup>(b)</sup>        | X <sup>(b)</sup>         | Y <sup>(c)</sup>          | Y <sup>(c)</sup>      | Y <sup>(c)</sup>       | Y <sup>(c)</sup>      | Y <sup>(c)</sup>  | Y <sup>(c)</sup>  | Y <sup>(c)</sup>  | Y <sup>(c)</sup>  |
| 1                            | Geosmine                 | X <sup>(b)</sup>       | X <sup>(b)</sup>        | X <sup>(b)</sup>         | X <sup>(b)</sup>          | X <sup>(b)</sup>      | X <sup>(b)</sup>       | X <sup>(b)</sup>      | X <sup>(b)</sup>  | X <sup>(b)</sup>  | X <sup>(b)</sup>  | X <sup>(b)</sup>  |
|                              |                          |                        |                         |                          |                           |                       |                        |                       |                   |                   |                   |                   |
| 2                            | Chloride                 | 1370                   | 1202                    | 278                      | 1047                      | 1127                  | 1138                   | 1091                  | 1418              | 1067              | 1069              | 1060              |
| 2                            | Bromide                  | <100                   | <120                    | <120                     | <130                      | <100                  | <120                   | <120                  | <40               | <40               | <40               | <30               |

| Analysis method | Compound       | Conventional raw juice | Conventional thin juice | Conventional thick juice | Raw beet juice 3, 4 and 5 | Filtered beet juice 6 | Clarified beet juice 3 | Filtered beet juice 5 | Beet syrup 3 | Beet syrup 4 | Beet syrup 5 | Beet syrup 6 |
|-----------------|----------------|------------------------|-------------------------|--------------------------|---------------------------|-----------------------|------------------------|-----------------------|--------------|--------------|--------------|--------------|
| 2               | Nitrate        | 1516                   | 1233                    | 317                      | 814                       | 1502                  | 1257                   | 788                   | 1754         | 892          | 893          | 1473         |
| 2               | Malate         | 901                    | 630                     | 168                      | 930                       | 1033                  | 778                    | 806                   | 1140         | 906          | 981          | 1178         |
| 2               | Sulfate        | 2867                   | 1752                    | 544                      | 302                       | 333                   | 359                    | 309                   | 395          | 322          | 322          | 368          |
| 2               | Oxalate        | 3682                   | <120                    | 29                       | 3663                      | 4178                  | 3293                   | 3152                  | 3070         | 3216         | 3221         | 3240         |
| 2               | Phosphate      | 2496                   | <120                    | 3                        | 2326                      | 2676                  | 1257                   | 1939                  | 2193         | 2485         | 2489         | 3093         |
| 2               | Nitrite        | 46                     | 43                      | 85                       | <10                       | <5                    | <10                    | 18                    | <3           | 4            | <3           | <3           |
|                 |                |                        |                         |                          |                           |                       |                        |                       |              |              |              |              |
| 3               | Citric acid    | 3257                   | 700                     | 181                      | 3605                      | 4413                  | 4012                   | 3394                  | 4240         | 3509         | 3514         | 4713         |
| 3               | Malic acid     | 876                    | 665                     | 200                      | 988                       | 1127                  | 778                    | 727                   | 1067         | 789          | 908          | 1296         |
| 3               | Lactic acid    | 4257                   | 3629                    | 1028                     | 500                       | 939                   | 1737                   | 2485                  | 599          | 1067         | 952          | 515          |
| 3               | Formic acid    | <200                   | 337                     | 114                      | <260                      | <200                  | <240                   | <240                  | <400         | <400         | <400         | <150         |
| 3               | Acetic acid    | 1968                   | 1014                    | 271                      | 413                       | 845                   | 1078                   | 1455                  | 453          | 687          | 512          | 515          |
| 3               | Propionic acid | <200                   | <250                    | <60                      | <260                      | <200                  | <240                   | <240                  | <400         | <400         | <400         | <150         |
| 3               | Butyric acid   | <200                   | <250                    | <60                      | <260                      | <200                  | <240                   | <240                  | <400         | <400         | <400         | <150         |

# EP 3 783 115 A1

| Analysis method | Compound                   | Conventional raw juice | Conventional thin juice | Conventional thick juice | Raw beet juice 3, 4 and 5 | Filtered beet juice 6 | Clarified beet juice 3 | Filtered beet juice 5 | Beet syrup 3 | Beet syrup 4 | Beet syrup 5 | Beet syrup 6      |
|-----------------|----------------------------|------------------------|-------------------------|--------------------------|---------------------------|-----------------------|------------------------|-----------------------|--------------|--------------|--------------|-------------------|
| 3               | Pyrrolidonecarboxylic acid | 354                    | 2274                    | 672                      | <250                      | <200                  | <240                   | <240                  | <365         | <365         | <365         | 236               |
| 4               | Aspartic acid              | 1133                   | 945                     | 814                      | 987                       | NM <sup>(d)</sup>     | 842                    | 647                   | 1075         | 926          | 986          | 611               |
| 4               | Serine/Asparagine          | 1310                   | 966                     | 493                      | 907                       | NM <sup>(d)</sup>     | 1143                   | 770                   | 977          | 672          | 704          | 949               |
| 4               | Glutamic acid              | 566                    | 747                     | 611                      | 518                       | NM <sup>(d)</sup>     | 349                    | 312                   | 822          | 295          | 519          | 37                |
| 4               | Glycine                    | 100                    | 134                     | 109                      | 69                        | NM <sup>(d)</sup>     | 83                     | <60                   | 96           | 55           | 63           | 51                |
| 4               | Histidine/Glutamine        | 2474                   | 472                     | 82                       | 1809                      | NM <sup>(d)</sup>     | 2150                   | 2669                  | 1526         | 1111         | 1099         | 2560              |
| 4               | Arginine                   | 181                    | 80                      | 72                       | 94                        | NM <sup>(d)</sup>     | 87                     | ND <sup>(a)</sup>     | 115          | 102          | 104          | 80                |
| 4               | Threonine                  | 271                    | 185                     | 122                      | 170                       | NM <sup>(d)</sup>     | 186                    | 150                   | 183          | 142          | 150          | 176               |
| 4               | Alanine                    | 452                    | 447                     | 344                      | 305                       | NM <sup>(d)</sup>     | 331                    | 327                   | 451          | 281          | 273          | 327               |
| 4               | Proline                    | ND <sup>(a)</sup>      | ND <sup>(a)</sup>       | ND <sup>(a)</sup>        | <350                      | NM <sup>(d)</sup>     | <300                   | 132                   | <75          | <75          | <75          | 144               |
| 4               | γ-Aminobutyric acid        | 1000                   | 947                     | 536                      | 959                       | NM <sup>(d)</sup>     | 1335                   | 1198                  | 755          | 798          | 693          | 1540              |
| 4               | Cysteine                   | ND <sup>(a)</sup>      | ND <sup>(a)</sup>       | ND <sup>(a)</sup>        | <60                       | NM <sup>(d)</sup>     | <60                    | ND <sup>(a)</sup>     | <15          | <15          | <15          | 43                |
| 4               | Tyrosine                   | 403                    | 694                     | 375                      | 72                        | NM <sup>(d)</sup>     | 106                    | ND <sup>(a)</sup>     | 236          | 117          | 100          | ND <sup>(a)</sup> |

| Analysis method | Compound               | Conventional raw juice | Conventional thin juice | Conventional thick juice | Raw beet juice 3, 4 and 5 | Filtered beet juice 6 | Clarified beet juice 3 | Filtered beet juice 5 | Beet syrup 3 | Beet syrup 4 | Beet syrup 5 | Beet syrup 6      |
|-----------------|------------------------|------------------------|-------------------------|--------------------------|---------------------------|-----------------------|------------------------|-----------------------|--------------|--------------|--------------|-------------------|
| 4               | Valine                 | 249                    | 230                     | 172                      | 149                       | NM <sup>(d)</sup>     | 173                    | 152                   | 198          | 145          | 149          | 168               |
| 4               | Methionine             | 91                     | 67                      | 69                       | <60                       | NM <sup>(d)</sup>     | <60                    | <60                   | 82           | 70           | 73           | 52                |
| 4               | Lysine                 | 105                    | 77                      | 51                       | <60                       | NM <sup>(d)</sup>     | <60                    | ND <sup>(a)</sup>     | 74           | 43           | 57           | 40                |
| 4               | Isoleucine             | 365                    | 348                     | 256                      | 269                       | NM <sup>(d)</sup>     | 306                    | 237                   | 334          | 245          | 256          | 281               |
| 4               | Leucine                | 398                    | 358                     | 254                      | 242                       | NM <sup>(d)</sup>     | 267                    | 230                   | 306          | 225          | 234          | 229               |
| 4               | Phenylalanine          | 123                    | 96                      | 100                      | 72                        | NM <sup>(d)</sup>     | 68                     | <60                   | 106          | 93           | 95           | 42                |
| 4               | Total free amino acids | 9222                   | 6793                    | 4461                     | 6622                      | NM <sup>(d)</sup>     | 7426                   | NM <sup>(d)</sup>     | 7335         | 5321         | 5554         | NM <sup>(d)</sup> |
| 5               | Dry matter             | wt%                    | wt%                     | wt%                      | wt%                       | wt%                   | wt%                    | wt%                   | wt%          | wt%          | wt%          | wt%               |
| 6               | Sucrose content        | 18.1                   | 18.7                    | 69.2                     | 17.2                      | 23.1                  | 16.8                   | 16.9                  | 68.4         | 68.3         | 68.1         | 67.5              |
| 6               | Sucrose content        | wt%                    | wt%                     | wt%                      | wt%                       | wt%                   | wt%                    | wt%                   | wt%          | wt%          | wt%          | wt%               |
| 6               | Sucrose content        | 17.0                   | 18.2                    | 66.3                     | 16.0                      | 18.8                  | 14.5                   | 13.8                  | 61.5         | 63.8         | 62.8         | 59.8              |

- (a) Not detected  
 (b) Qualitatively detected  
 (c) Qualitatively detected, two times higher than in conventional process  
 (d) Not measured

## Example 14: sensory analysis

[0165] Sensory characteristics of (a) a thick juice produced using a conventional process comprising extraction at a temperature of about 72-74°C and raw juice purification steps comprising liming, carbonation, filtration and softening and (b) a beet syrup (produced with a process) according to the invention (**beet juice 3**) were evaluated by 10 individuals participants. Test results are given in Table 3.

[0166] As can be inferred from Table 3, generally speaking, beet syrup (produced with a process) according to the invention was found to be more palatable than conventional thick juice, making the beet syrup according to the invention suitable for direct human consumption or as a sweetener in food applications for human consumption. The same results are expected for a comparison between molasses produced using a conventional process and molasses (produced with a process) according to the invention. Likewise, The same results are expected for a comparison between thin juice produced using a conventional process and filtered sugar beet juice/clarified sugar beet juice (produced with a process) according to the invention.

**Table 3: sensory characteristics**

|                         | Conventional thick juice |         |          | Beet syrup 3<br>(according to invention) |         |          |
|-------------------------|--------------------------|---------|----------|------------------------------------------|---------|----------|
| Taste                   | Positive                 | Neutral | Negative | Positive                                 | Neutral | Negative |
| hazelnut                |                          |         | x        |                                          | x       |          |
| sweet                   |                          |         | x        | x                                        |         |          |
| general                 |                          |         | x        | x                                        |         |          |
| honey                   |                          |         |          | x                                        |         |          |
| honey taste             |                          |         | x        | x                                        |         |          |
| urea taste              |                          |         | x        |                                          | x       |          |
| caramel                 |                          | x       |          |                                          | x       |          |
| nutty                   |                          |         | x        |                                          |         |          |
| caramel                 | x                        |         |          |                                          |         |          |
| liquorice (salty)       |                          |         |          |                                          |         | x        |
| fruit, dry apricot/plum |                          |         |          | x                                        |         |          |
| coconut                 |                          |         |          | x                                        |         |          |
| nutty                   | x                        |         |          |                                          | x       |          |
| sweetness               | x                        |         |          |                                          | x       |          |

|                                   |   |   |   |   |   |   |
|-----------------------------------|---|---|---|---|---|---|
| liquorice                         |   | x |   | x |   |   |
| salty                             |   | x |   |   |   | x |
| sweet                             | x |   |   | x |   |   |
| honey flavor                      |   |   | x | x |   |   |
| liquorice                         |   |   | x | x |   |   |
| cattlefeed                        |   |   | x |   | x |   |
| salty                             |   | x |   |   |   | x |
| cream aftertaste                  | x |   |   |   | x |   |
| sweet                             | x |   |   |   |   | x |
| burning tingling                  |   |   | x |   | x |   |
| mild aftertaste                   |   |   | x | x |   |   |
| nutty hazelnut                    |   | x |   |   |   |   |
| cane molasses/sugar<br>cane syrup |   |   |   | x |   |   |

## Claims

1. A method for the preparation of sugar beet syrup from whole sugar beet, said method comprising the distinct steps of:

a) providing whole sugar beets;

b) reducing the size and releasing juice from the sugar beet material by subjecting the whole sugar beets to:

- shredding, slicing or milling, followed by a treatment selected from the group consisting of pulsed electric field (PEF) treatment, fermentation, acidification, freezing and thawing, and combinations thereof;
- pulsed electric field, followed by shredding, slicing or milling; or
- milling,

resulting in a treated sugar beet material comprising sugar beet juice and pulp or mush;

c) separating sugar beet juice from pulp or mush by subjecting the treated sugar beet material obtained in step b) to a coarse physical separation, wherein the coarse physical separation at least comprises passing the sugar beet juice over a solid filter medium with mesh openings between above 10  $\mu\text{m}$  and 2000  $\mu\text{m}$ , and preferably comprises one or more pressing cycles with optional soaking prior to applying said solid filter medium, resulting in filtered sugar beet juice with a sucrose content of between 5 and 30 wt.%;

d) optionally subjecting the filtered sugar beet juice of step c) to a fine physical purification step, resulting in clarified sugar beet juice with a sucrose content of between 5 and 30 wt.%;

e) subjecting the filtered sugar beet juice of step c) or the clarified sugar beet juice of step d) to a concentration step resulting in sugar beet syrup with a sucrose content of between 30 and 86 wt.%, preferably between 60 and 80 wt.%, more preferably between 63 and 75 wt.%, even more preferably between 67 and 71 wt.%,

wherein no alkalization agent is employed, wherein the temperature of the sugar beets, sugar beet material, treated sugar beet material, sugar beet juice and filtered sugar beet juice in steps a) to c) does not exceed 60°C, preferably does not exceed 50°C, more preferably does not exceed 40°C, even more preferably does not exceed 30°C, and wherein the temperature of the clarified sugar beet juice in step d) does not exceed 70°C, preferably does not exceed 60°C, more preferably does not exceed 50°C, even more preferably does not exceed 40°C, and

- wherein the method does not comprise membrane filtration using a membrane with a pore size of 0.1  $\mu\text{m}$  or smaller, and does not comprise membrane filtration using a membrane having a cut off of 102 kDa or smaller; or
- wherein the method does not comprise ultrafiltration, nanofiltration and reverse osmosis; or
- wherein the method does not comprise ultrafiltration.

2. The method according to claim 1, wherein the coarse physical separation in step c) further comprises one or more selected from cocurrent or countercurrent extraction, static settling, dynamic settling, spiral plate centrifuging, disk stack centrifuging, decanting, screw pressing, plunger pressing, belt pressing, precoat filtration, flotation, shaker screening, hydraulic cyclone separation and hydraulic upflow classification.

3. The method according to claim 1 or 2, wherein the solid filter medium in step c) has mesh openings between 80 and 1000  $\mu\text{m}$ , preferably between 100 and 750  $\mu\text{m}$ , more preferably between 150 and 500  $\mu\text{m}$ , even more preferably between 200 and 300  $\mu\text{m}$ .

4. The method according to any one of claims 1 - 3, wherein step d) is mandatory and wherein the temperature of the sugar beets, sugar beet material, treated sugar beet material, sugar beet juice and filtered sugar beet juice in steps a) to c) does not exceed 50°C, preferably does not exceed 40°C, even more preferably does not exceed 30°C and wherein the temperature of the clarified sugar beet juice in step d) is between 50 and 70°C.

5. The method according to any one of claims 1 - 4, wherein step d) is mandatory and wherein the fine physical purification in step d) comprises or consists of microfiltration using a membrane with a pore size of between more than 0.1 and 10  $\mu\text{m}$ , preferably with a pore size of between 0.105 and 5  $\mu\text{m}$ , more preferably with a pore size of between 0.11 and 2.5  $\mu\text{m}$ , even more preferably with a pore size of between 0.12 and 1  $\mu\text{m}$ , still more preferably with a pore size of between 0.15 - 0.4  $\mu\text{m}$ .

6. The method according to any one of claims 1-5, wherein step b) comprises or consists of shredding, slicing or milling followed by pulsed electric field treatment, wherein step c) comprises or consists of one or more pressing cycles with optional soaking followed by filtration over a solid filter medium with mesh openings between above 10  $\mu\text{m}$  and

2000  $\mu\text{m}$ , preferably between 80 and 1000  $\mu\text{m}$ , more preferably between 100 and 750  $\mu\text{m}$ , even more preferably between 150 and 500  $\mu\text{m}$ , still more preferably between 200 and 300  $\mu\text{m}$ , wherein step d) is mandatory and wherein the fine physical purification of step d) comprises or consists of microfiltration using a membrane with a pore size of between more than 0.1 and 10  $\mu\text{m}$ , preferably with a pore size of between 0.105 and 5  $\mu\text{m}$ , more preferably with a pore size of between 0.11 and 2.5  $\mu\text{m}$ , even more preferably with a pore size of between 0.12 and 1  $\mu\text{m}$ , still more preferably with a pore size of between 0.15 - 0.4  $\mu\text{m}$ .

7. The method according to any one of claims 1 - 3, wherein step b) comprises or consists of shredding, slicing or milling followed by pulsed electric field treatment, wherein step c) comprises or consists of one or more pressing cycles with optional soaking followed by filtration over a solid filter medium with mesh openings between above 10  $\mu\text{m}$  and 2000  $\mu\text{m}$ , preferably between 80 and 1000  $\mu\text{m}$ , more preferably between 100 and 750  $\mu\text{m}$ , even more preferably between 150 and 500  $\mu\text{m}$ , still more preferably between 200 and 300  $\mu\text{m}$ , and wherein step d) is preferably not performed.

8. The method according to any one of claims 1 - 3, wherein step b) comprises or consists of shredding, slicing or milling followed by pulsed electric field treatment, wherein step c) comprises or consists of one or more pressing cycles with optional soaking followed by filtration over a solid filter medium with mesh openings between above 10  $\mu\text{m}$  and 2000  $\mu\text{m}$ , preferably between 80 and 1000  $\mu\text{m}$ , more preferably between 100 and 750  $\mu\text{m}$ , even more preferably between 150 and 500  $\mu\text{m}$ , still more preferably between 200 and 300  $\mu\text{m}$ , followed by one or more selected from cocurrent or countercurrent extraction, static settling, dynamic settling, spiral plate centrifuging, disk stack centrifuging, decanting, screw pressing, plunger pressing, belt pressing, precoat filtration, flotation, shaker screening, hydraulic cyclone separation and hydraulic upflow classification, preferably disc stack centrifuging, and wherein step d) is preferably not performed.

9. The method according to any one of claims 1-3, wherein step b) consists of milling, preferably hammer milling, wherein step c) comprises or consists of one or more pressing cycles with optional soaking followed by filtration over a solid filter medium with mesh openings between above 10  $\mu\text{m}$  and 2000  $\mu\text{m}$ , preferably between 80 and 1000  $\mu\text{m}$ , more preferably between 100 and 750  $\mu\text{m}$ , even more preferably between 150 and 500  $\mu\text{m}$ , still more preferably between 200 and 300  $\mu\text{m}$ , and wherein step d) is preferably not performed.

10. The method according to any one of claims 1 - 9 wherein step e) comprises subjecting the filtered sugar beet juice of step c) or the clarified sugar beet juice of step d) to an evaporation step wherein the juice temperature does not exceed 130°C, preferably does not exceed 112°C, more preferably does not exceed 105°C.

11. The method according to any one of claims 1 - 10, further comprising the step of:  
f) subjecting the sugar beet syrup of step e) to a further concentration step resulting in crystallized sugar and sugar beet molasses.

12. The method according to claim 11 wherein the temperature in step f) is between 40 and 130 °C, preferably between 45 and 112 °C, more preferably between 50 and 105 °C.

13. The method according to claim 11 or 12 wherein no alkalization agent is employed.

14. The method according to any one of claims 1 - 10, wherein the method is a method for the preparation of a sugar beet syrup **characterized by** between 500 and 7000 mg/kg, preferably between 800 and 5000 mg/kg, more preferably between 1000 and 3500 mg/kg of phosphate, and one or more of the following properties, wherein the concentrations are based on total dissolved dry solids weight:

- i) substantially free or free of 2,5-dimethylpyrazine;
- ii) substantially free or free of 2-ethyl-3-methylpyrazine;
- iii) substantially free or free of 2,3,5-trimethylpyrazine;
- iv) less than 500 mg/kg, preferably less than 450 mg/kg, more preferably less than 400 mg/kg, even more preferably less than 350 mg/kg of sulfate;
- v) less than 600 mg/kg, preferably less than 500 mg/kg, more preferably less than 400 mg/kg, even more preferably less than 370 mg/kg of pyrrolidone carbonic acid;
- vi) between 1000 and 7000 mg/kg, preferably between 1500 and 5000 mg/kg, more preferably between 2000 and 4000 mg/kg, even more preferably between 2500 and 3500 mg/kg of oxalate; and
- vii) more than 500 mg/kg, preferably more than 650 mg/kg, more preferably more than 850 mg/kg, even more



preferably more than 1000 mg/kg, of the combined amount of histidine and glutamine.

- 5 15. The method according to any one of claims 11 - 13, wherein the method is a method for the preparation of a crystallized sugar and sugar beet molasses, wherein the sugar beet molasses is **characterized by** between 100 and 50000 mg/kg, preferably between 1000 and 40000 mg/kg, more preferably between 5000 and 30000 mg/kg, still more preferably between 10000 and 25000 mg/kg of phosphate, and one or more of the following properties, wherein the concentrations are based on total dissolved dry solids weight:

- 10 i) substantially free or free of 2,5-dimethylpyrazine;  
 ii) substantially free or free of 2-ethyl-3-methylpyrazine;  
 iii) substantially free or free of 2,3,5-trimethylpyrazine;  
 iv) less than 11000 mg/kg, preferably less than 9000 mg/kg, more preferably less than 7000 mg/kg, even more preferably less than 5000 mg/kg of sulfate;  
 15 v) less than 8000 mg/kg, preferably less than 7500 mg/kg, more preferably less than 7000 mg/kg, even more preferably less than 6500 mg/kg, still more preferably less than 6000 mg/kg of pyrrolidone carbonic acid;  
 vi) between 1000 and 100000 mg/kg, preferably between 3000 and 80000 mg/kg, more preferably between 9000 and 70000 mg/kg, even more preferably between 12000 and 60000 mg/kg, still more preferably between 15000 and 50000 mg/kg of oxalate; and  
 20 vii) more than 300 mg/kg, preferably more than 600 mg/kg, more preferably more than 900 mg/kg, even more preferably more than 1200 mg/kg, of the combined amount of histidine and glutamine.

- 25 16. The method according to any one of claims 11 - 13, wherein the method is a method for the preparation of a crystallized sugar and sugar beet molasses **characterized by** the following crystallized sugar properties, wherein the concentrations are based on total dry solids weight:

- 30 i) substantially free or free of 2,5-dimethylpyrazine;  
 ii) substantially free or free of 2-ethyl-3-methylpyrazine;  
 iii) substantially free or free of 2,3,5-trimethylpyrazine; or  
 iv) a combination of i), ii) and iii).

17. The method according to any one of claims 1 - 16, wherein the pH in steps (a) to (e) is in the range of 0.5 - 7, preferably in the range of 3.5 - 7, more preferably in the range of 4.5 - 7.

- 35 18. The method according to any one of claims 1 - 17, wherein no demineralization or softening step is performed.

19. The method according to any one of claims 1 - 18, wherein said method does not comprise a chemical purification step.

- 40 20. Sugar beet syrup, crystallized sugar or sugar beet molasses obtainable by the method according to any one of claims 1 - 19.

- 45 21. Sugar beet syrup **characterized by** between 500 and 7000 mg/kg, preferably between 800 and 5000 mg/kg, more preferably between 1000 and 3500 mg/kg of phosphate, and one or more of the following properties, wherein the concentrations are based on total dissolved dry solids weight:

- 50 i) substantially free or free of 2,5-dimethylpyrazine;  
 ii) substantially free or free of 2-ethyl-3-methylpyrazine;  
 iii) substantially free or free of 2,3,5-trimethylpyrazine;  
 iv) less than 500 mg/kg, preferably less than 450 mg/kg, more preferably less than 400 mg/kg, even more preferably less than 350 mg/kg of sulfate;  
 v) less than 600 mg/kg, preferably less than 500 mg/kg, more preferably less than 400 mg/kg, even more preferably less than 370 mg/kg of pyrrolidone carbonic acid;  
 vi) between 1000 and 7000 mg/kg, preferably between 1500 and 5000 mg/kg, more preferably between 2000 and 4000 mg/kg, even more preferably between 2500 and 3500 mg/kg of oxalate; and  
 55 vii) more than 500 mg/kg, preferably more than 650 mg/kg, more preferably more than 850 mg/kg, even more preferably more than 1000 mg/kg, of the combined amount of histidine and glutamine.

22. Sugar beet molasses **characterized by** between 100 and 50000 mg/kg, preferably between 1000 and 40000 mg/kg, more preferably between 5000 and 30000 mg/kg, still more preferably between 10000 and 25000 mg/kg of phosphate,

and one or more of the following properties, wherein the concentrations are based on total dissolved dry solids weight:

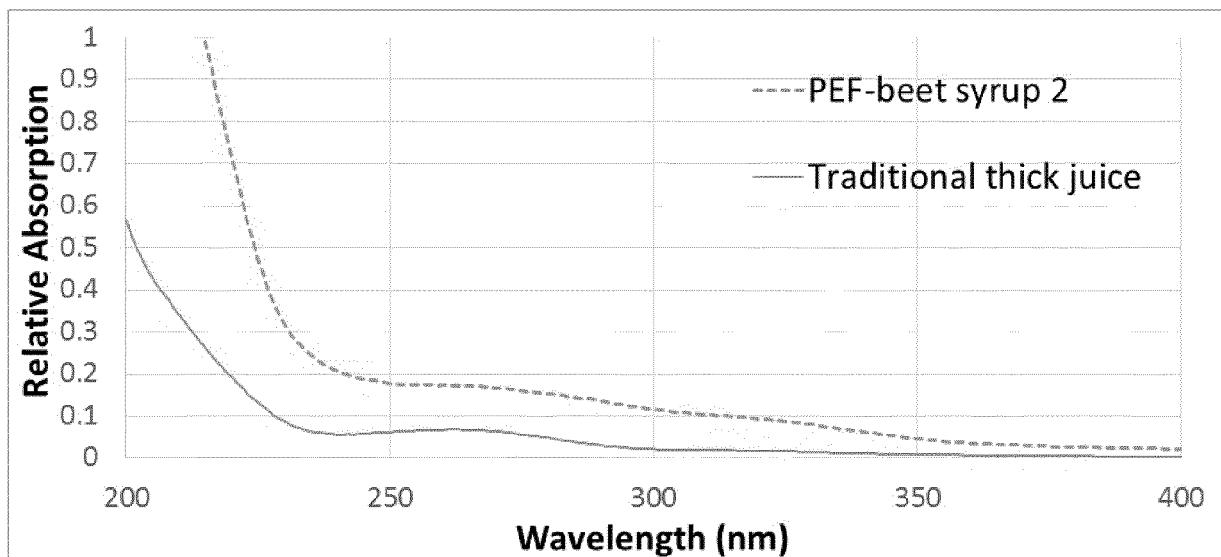
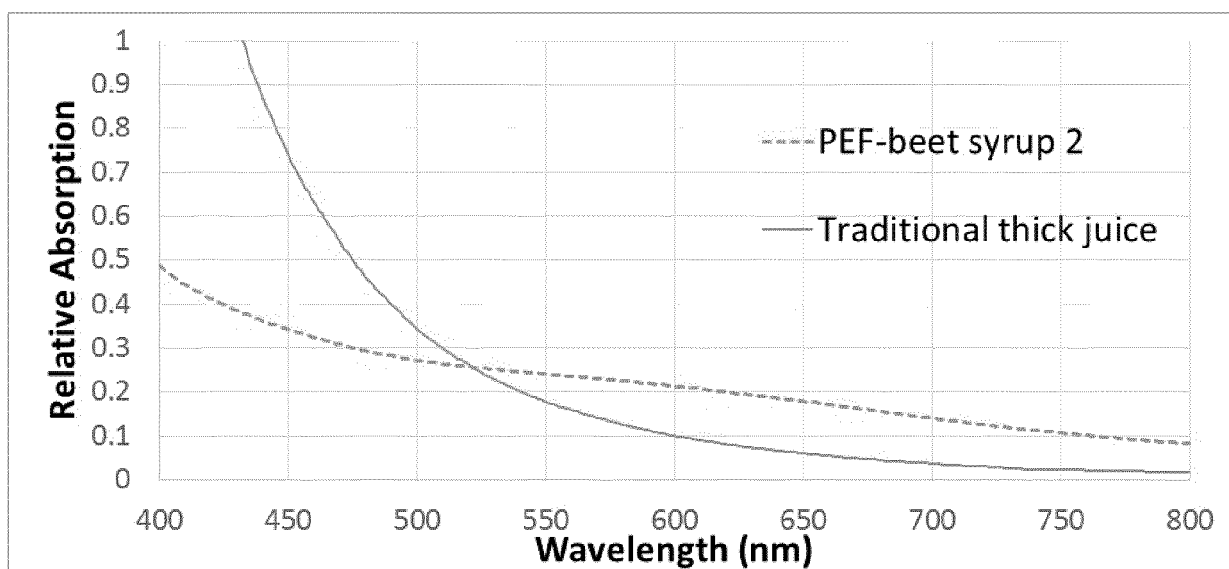
- i) substantially free or free of 2,5-dimethylpyrazine;
- ii) substantially free or free of 2-ethyl-3-methylpyrazine;
- iii) substantially free or free of 2,3,5-trimethylpyrazine;
- iv) less than 11000 mg/kg, preferably less than 9000 mg/kg, more preferably less than 7000 mg/kg, even more preferably less than 5000 mg/kg of sulfate;
- v) less than 8000 mg/kg, preferably less than 7500 mg/kg, more preferably less than 7000 mg/kg, even more preferably less than 6500 mg/kg, still more preferably less than 6000 mg/kg of pyrrolidone carbonic acid;
- vi) between 1000 and 100000 mg/kg, preferably between 3000 and 80000 mg/kg, more preferably between 9000 and 70000 mg/kg, even more preferably between 12000 and 60000 mg/kg, still more preferably between 15000 and 50000 mg/kg of oxalate; and
- vii) more than 300 mg/kg, preferably more than 600 mg/kg, more preferably more than 900 mg/kg, even more preferably more than 1200 mg/kg, of the combined amount of histidine and glutamine.

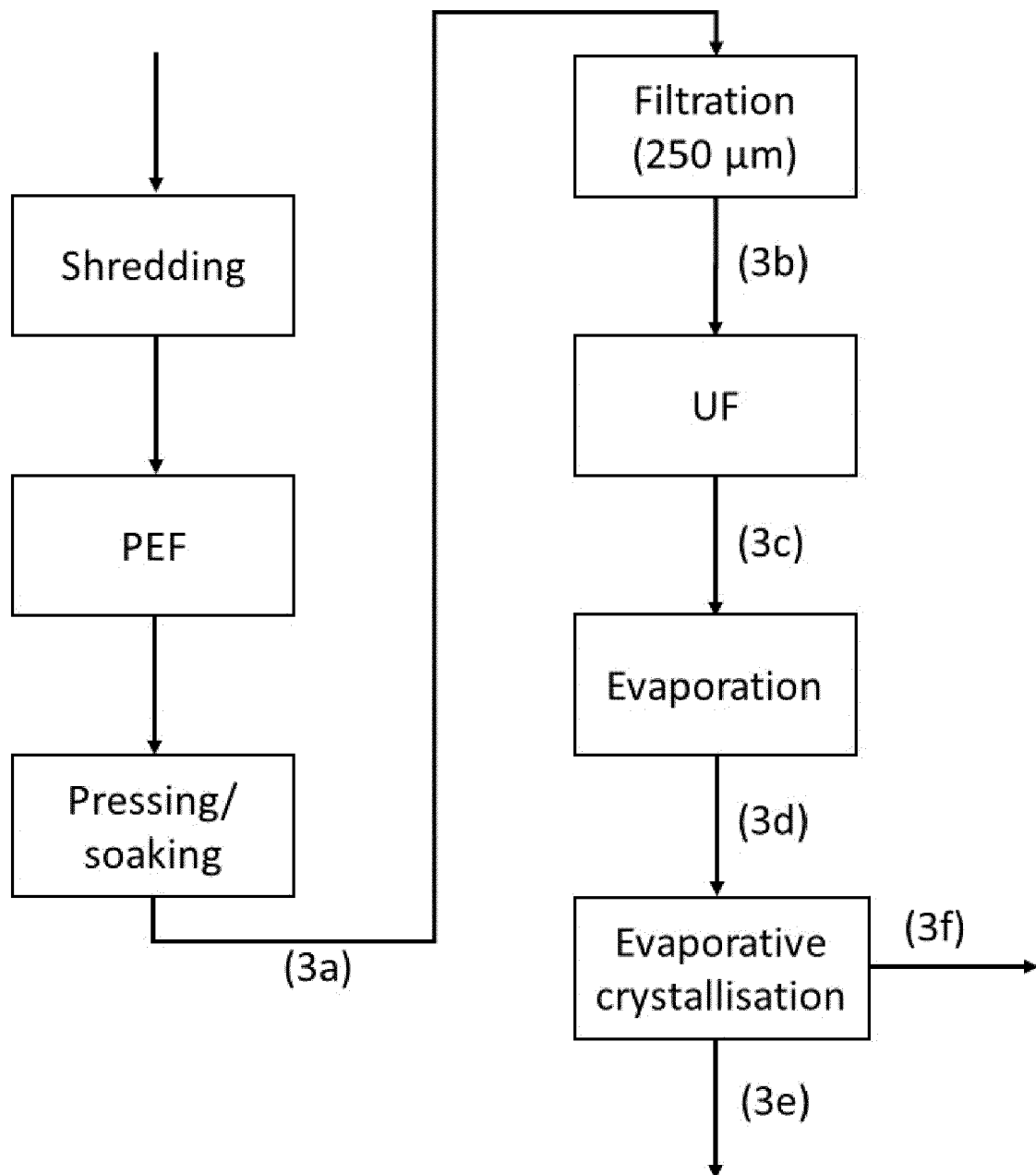
**23.** Crystallized sugar **characterized by** the following properties, wherein the concentrations are based on total dry solids weight:

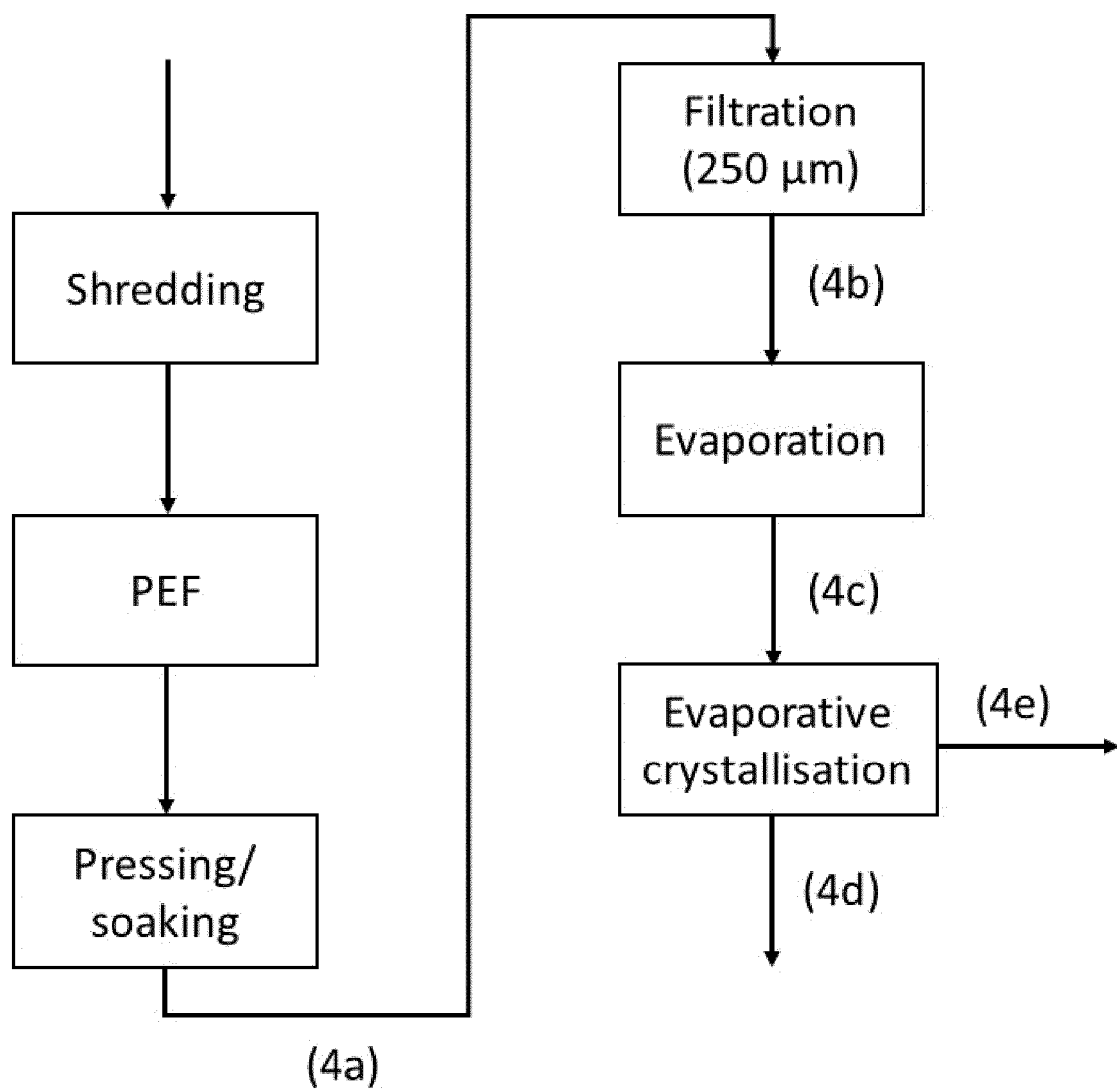
- i) substantially free or free of 2,5-dimethylpyrazine;
- ii) substantially free or free of 2-ethyl-3-methylpyrazine;
- iii) substantially free or free of 2,3,5-trimethylpyrazine; or
- iv) a combination of i), ii) and iii).

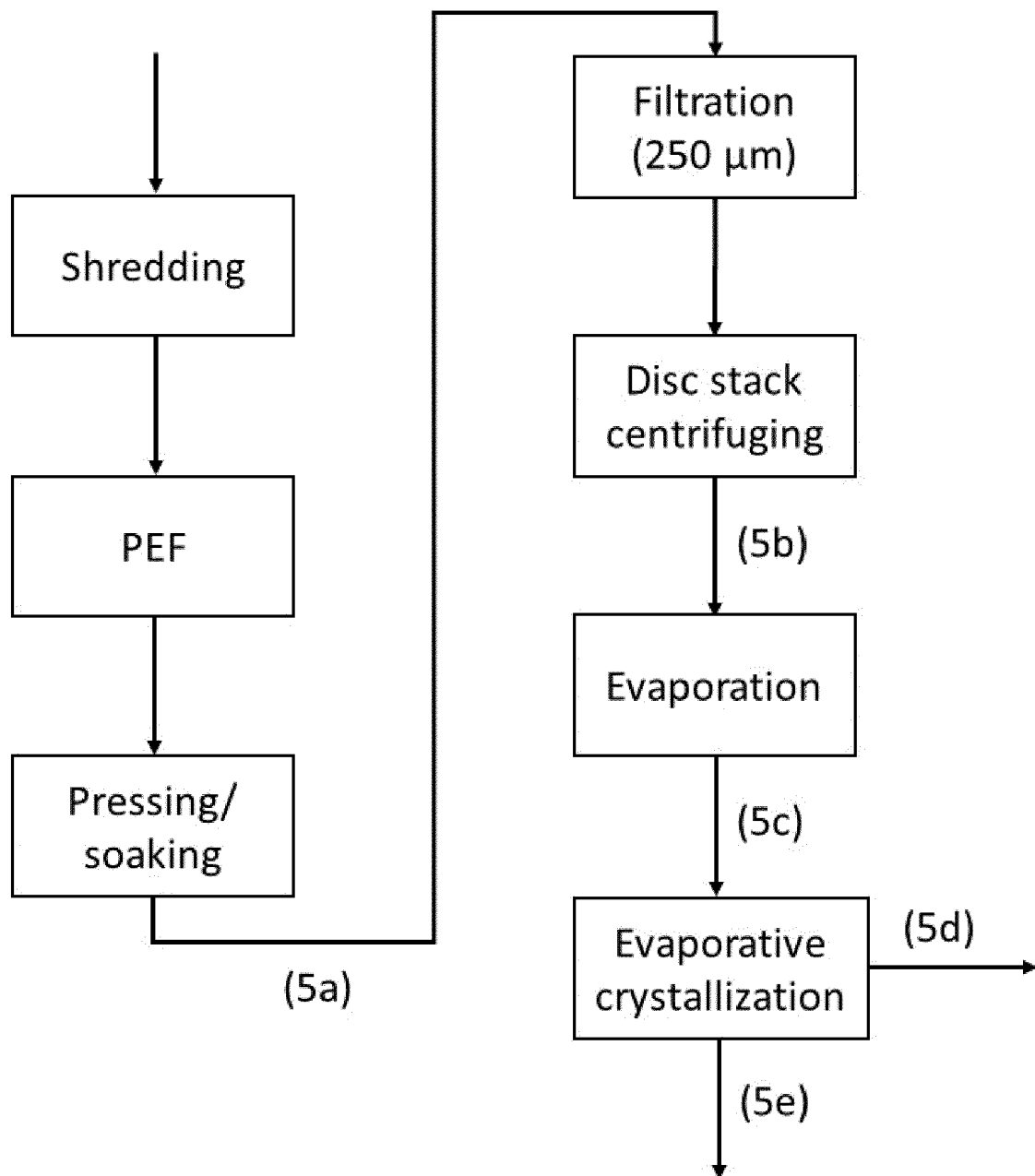
**24.** Food product for human consumption comprising the sugar beet syrup, sugar beet molasses or crystallized sugar according to any one of claims 20 - 23.

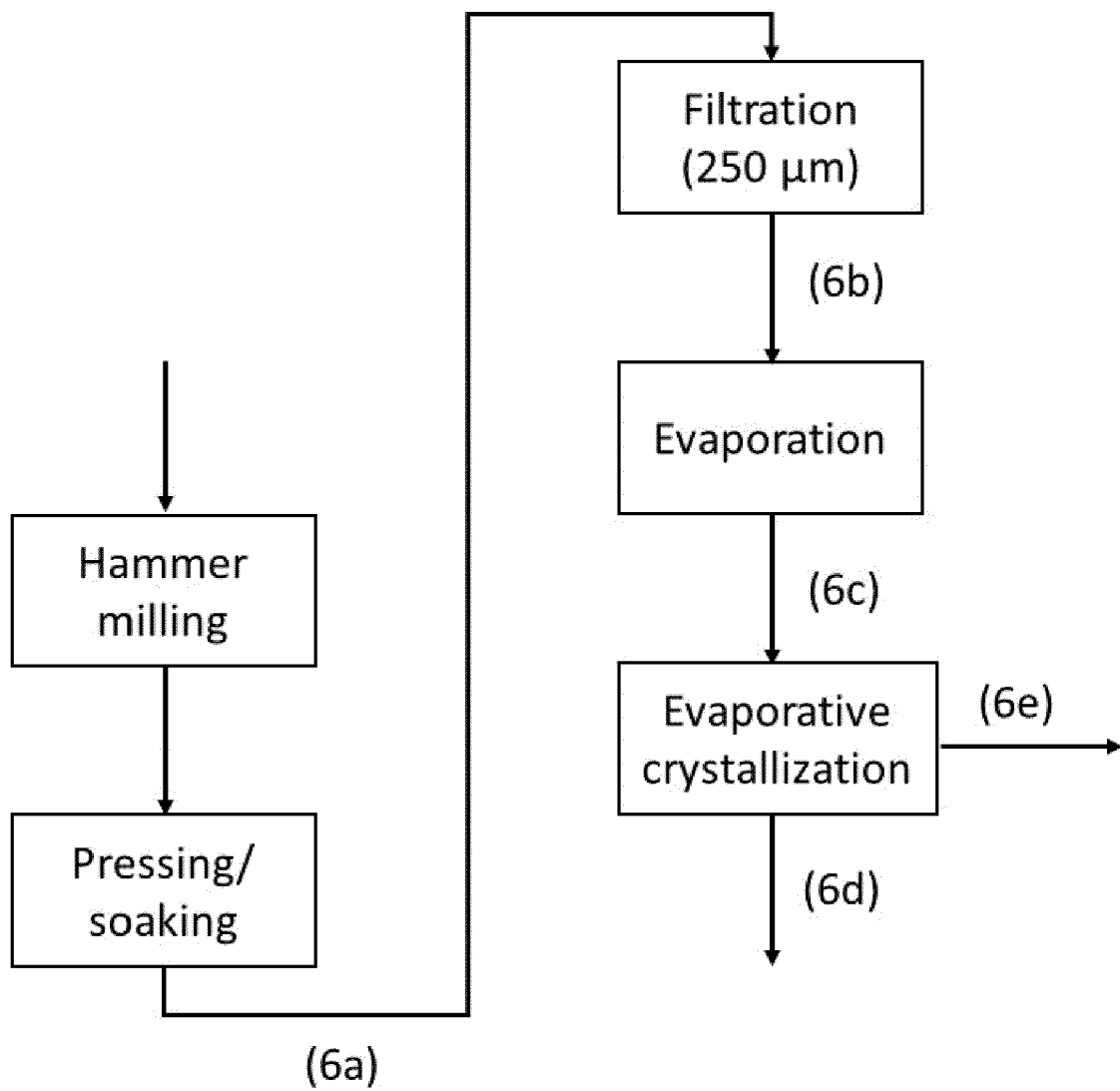
**25.** Use of the sugar beet syrup or sugar beet molasses according to any one of claims 20 - 22 as a food product for human consumption or as a sweetener in food products for human consumption, such as in liquorice, cereal bars and bakery products.

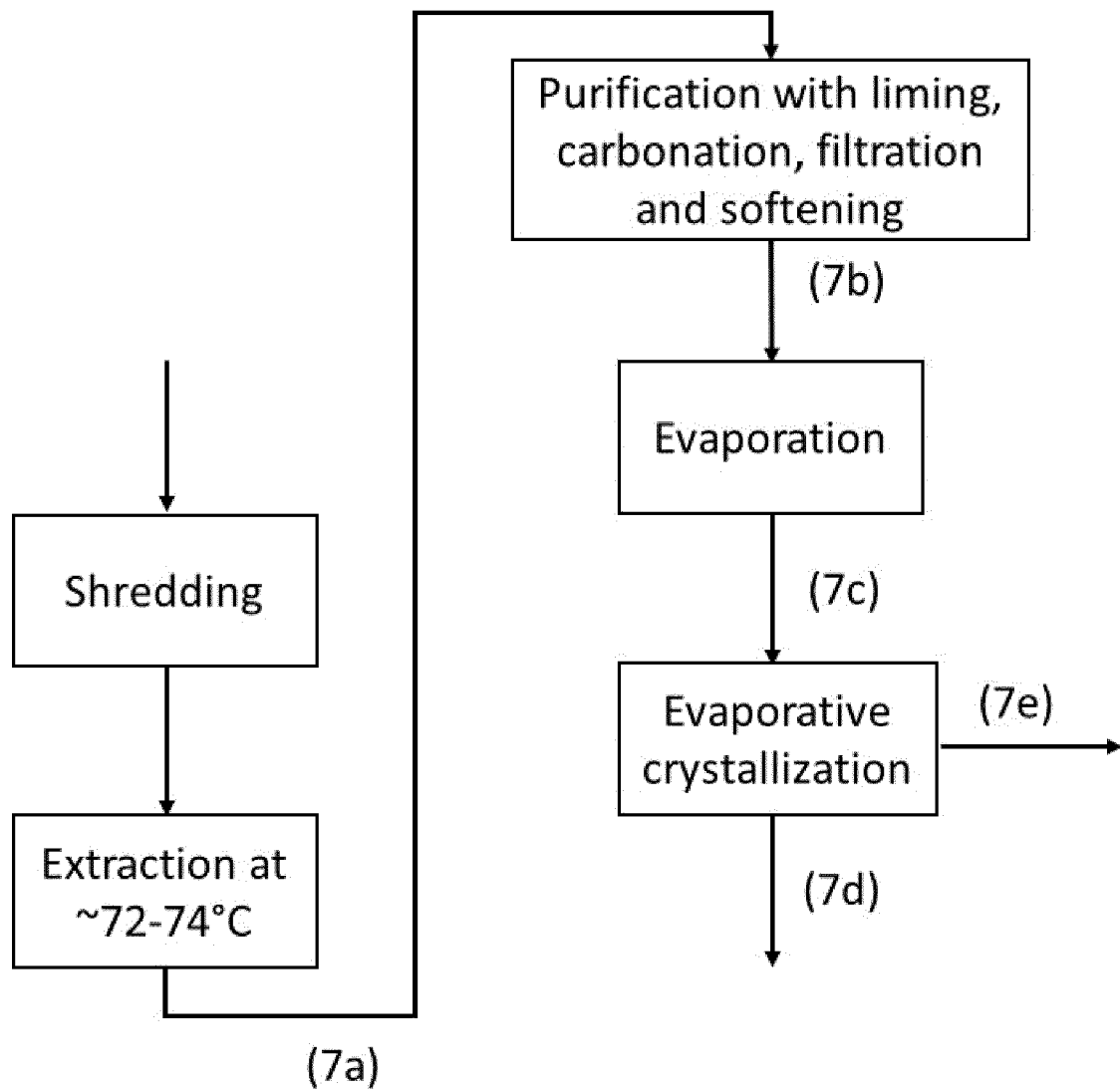
**Fig. 1****Fig. 2**

**Fig. 3**

**Fig. 4**

**Fig. 5**

**Fig. 6**

**Fig. 7**





## EUROPEAN SEARCH REPORT

 Application Number  
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| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                                                                                                                                                                                           |                                                             |                                             |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------|---------------------------------------------|
| Category                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | Citation of document with indication, where appropriate, of relevant passages                                                                                                                                                                                                                                                                                                             | Relevant to claim                                           | CLASSIFICATION OF THE APPLICATION (IPC)     |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | WO 99/64634 A1 (BEGHIN SAY ERIDANIA [FR]; ESTHIAGHI MOHAMMAD NAGHI [DE] ET AL.)<br>16 December 1999 (1999-12-16)<br>* examples 1-7 *                                                                                                                                                                                                                                                      | 1-25                                                        | INV.<br>C13B10/08                           |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | A.B. Jemai, E. Vorobiev: "Enhanced leaching from sugar beet cossettes by pulsed electric field - ScienceDirect", Journal of Food Engineering, vol. 59<br>2003, pages 405-412, XP055654517,<br>Retrieved from the Internet:<br>URL:https://www.sciencedirect.com/science/article/pii/S0260877402004995<br>[retrieved on 2019-12-20]<br>* Experimental procedure *                          | 1-25                                                        |                                             |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | LOGINOVA K V ET AL: "Pilot study of countercurrent cold and mild heat extraction of sugar from sugar beets, assisted by pulsed electric fields", JOURNAL OF FOOD ENGINEERING, BARKING, ESSEX, GB,<br>vol. 102, no. 4,<br>1 February 2011 (2011-02-01), pages 340-347, XP027449443,<br>ISSN: 0260-8774, DOI:<br>10.1016/J.JFOODENG.2010.09.010<br>[retrieved on 2010-09-25]<br>* Methods * | 1-25                                                        |                                             |
| The present search report has been drawn up for all claims                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                           |                                                             | TECHNICAL FIELDS SEARCHED (IPC)<br><br>C13B |
| Place of search<br><b>Munich</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                           | Date of completion of the search<br><b>11 December 2020</b> | Examiner<br><b>Graham, Judith</b>           |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document<br>T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>& : member of the same patent family, corresponding document |                                                                                                                                                                                                                                                                                                                                                                                           |                                                             |                                             |

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## EUROPEAN SEARCH REPORT

 Application Number  
 EP 20 19 2029

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| Place of search<br><b>Munich</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                        | Date of completion of the search<br><b>11 December 2020</b> | Examiner<br><b>Graham, Judith</b>       |
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