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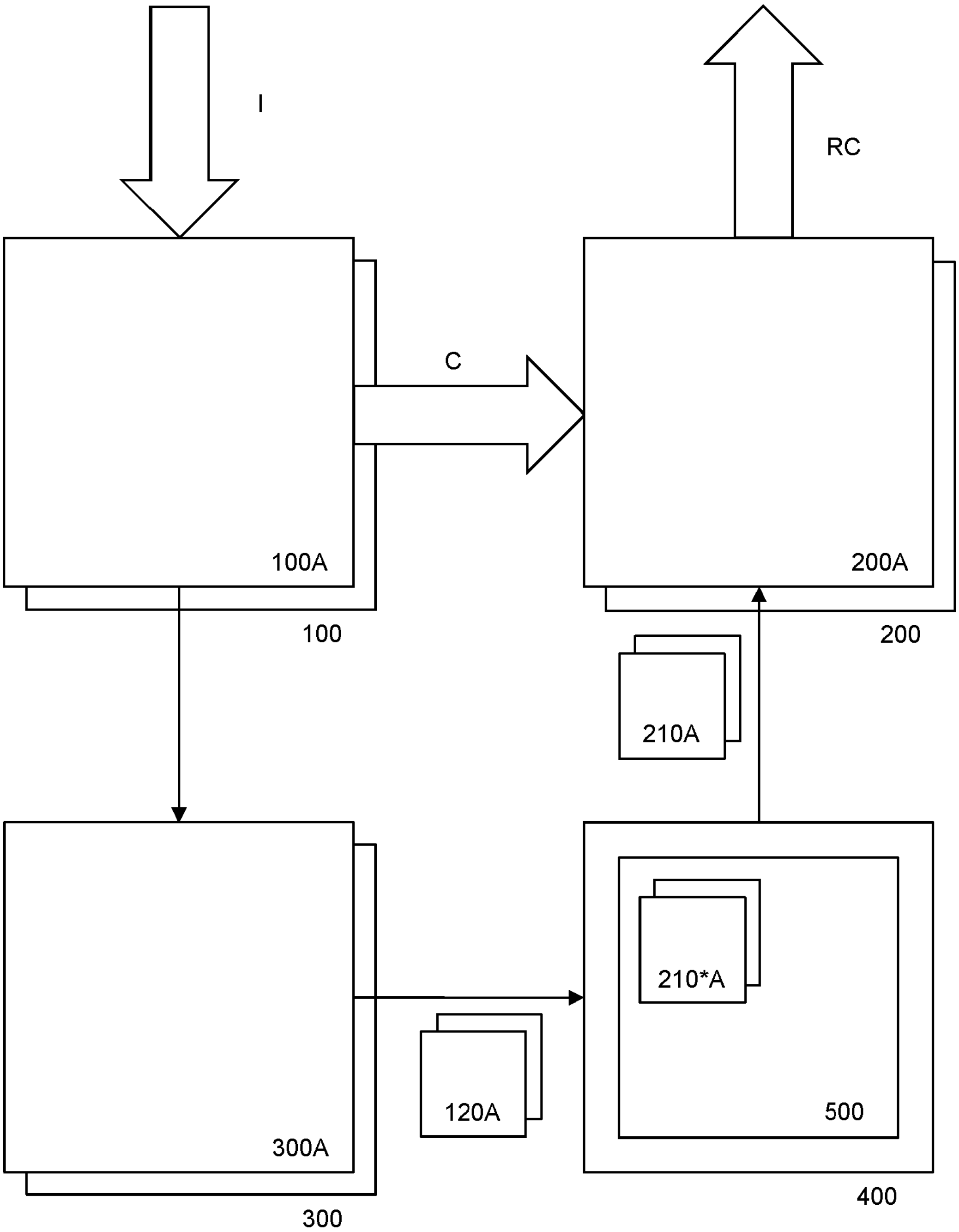


Fig. 1

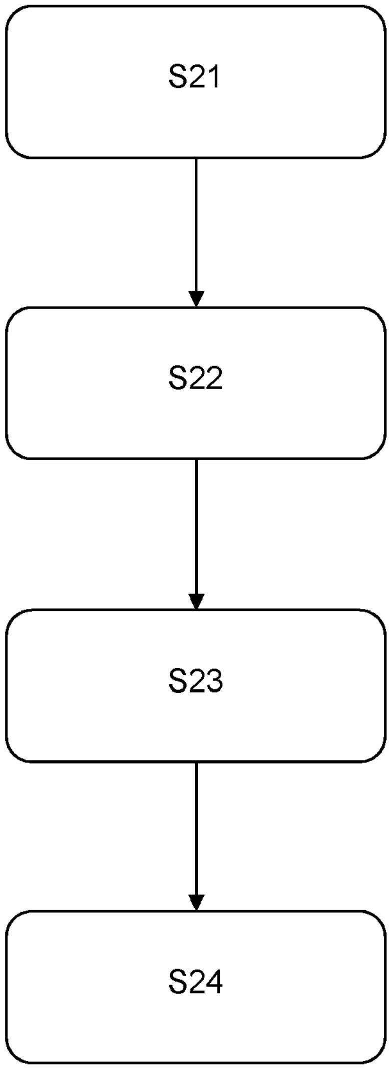


Fig. 2

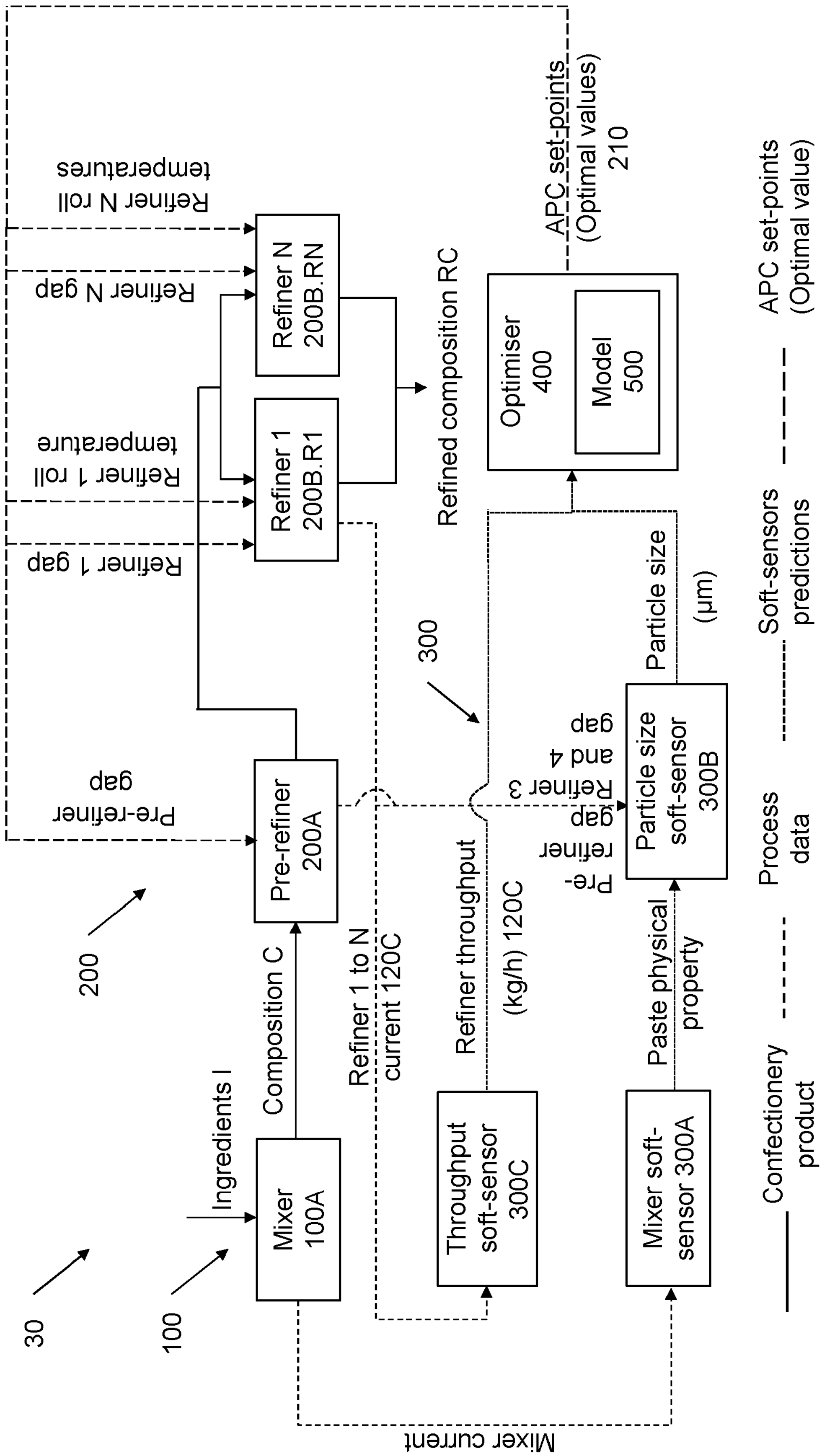

30
100
200
300
Mixer 100A
Ingredients I
Composition C
Pre-refiner 200A
Refiner 1 200B.R1
Refiner N 200B.RN
Refined composition RC
Pre-refiner gap
Refiner 1 gap
Refiner 1 roll temperature
Refiner N gap
Refiner N roll temperatures
Refiner 1 to N current 120C
Throughput soft-sensor 300C
Refiner throughput (kg/h) 120C
Mixer soft-sensor 300A
Paste physical property
Mixer current
Particle size soft-sensor 300B
Pre-refiner gap
Refiner 3 and 4 gap
Particle size (µm)
Optimiser 400
Model 500
APC set-points (Optimal values) 210
Confectionery product
Process data
Soft-sensors predictions
APC set-points (Optimal value)

Fig. 3

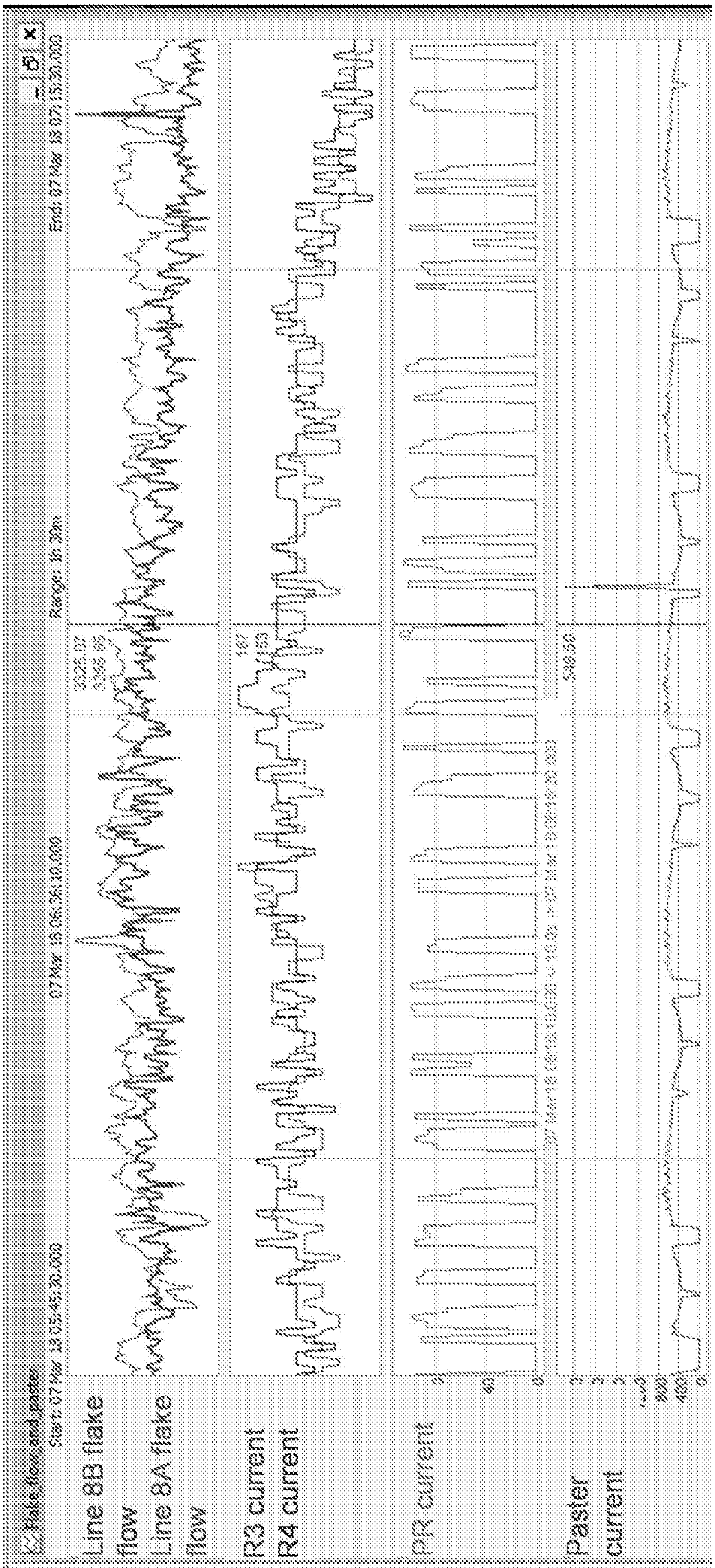
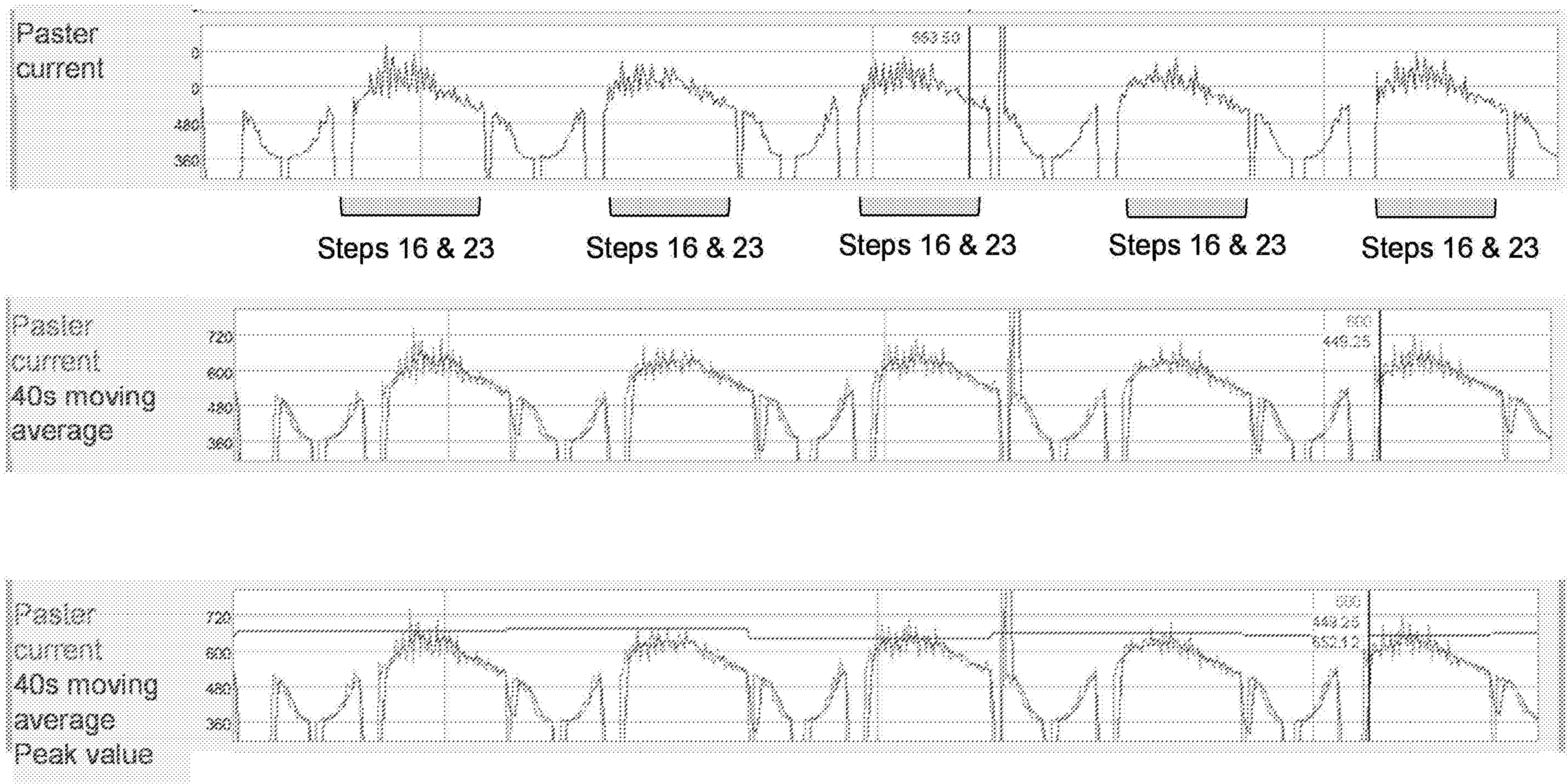

Flake flow and paster
Line 8B flake flow
Line 8A flake flow
R3 current
R4 current
PR current
Paster current
Range: 1h 30m

Fig. 4



Paster current
0
0
480
360
Steps 16 & 23
Steps 16 & 23
Steps 16 & 23
Steps 16 & 23
Steps 16 & 23
Paster current 40s moving average
720
600
480
360
449.25
Paster current 40s moving average Peak value
720
600
480
360
449.25
652.12

Fig. 5

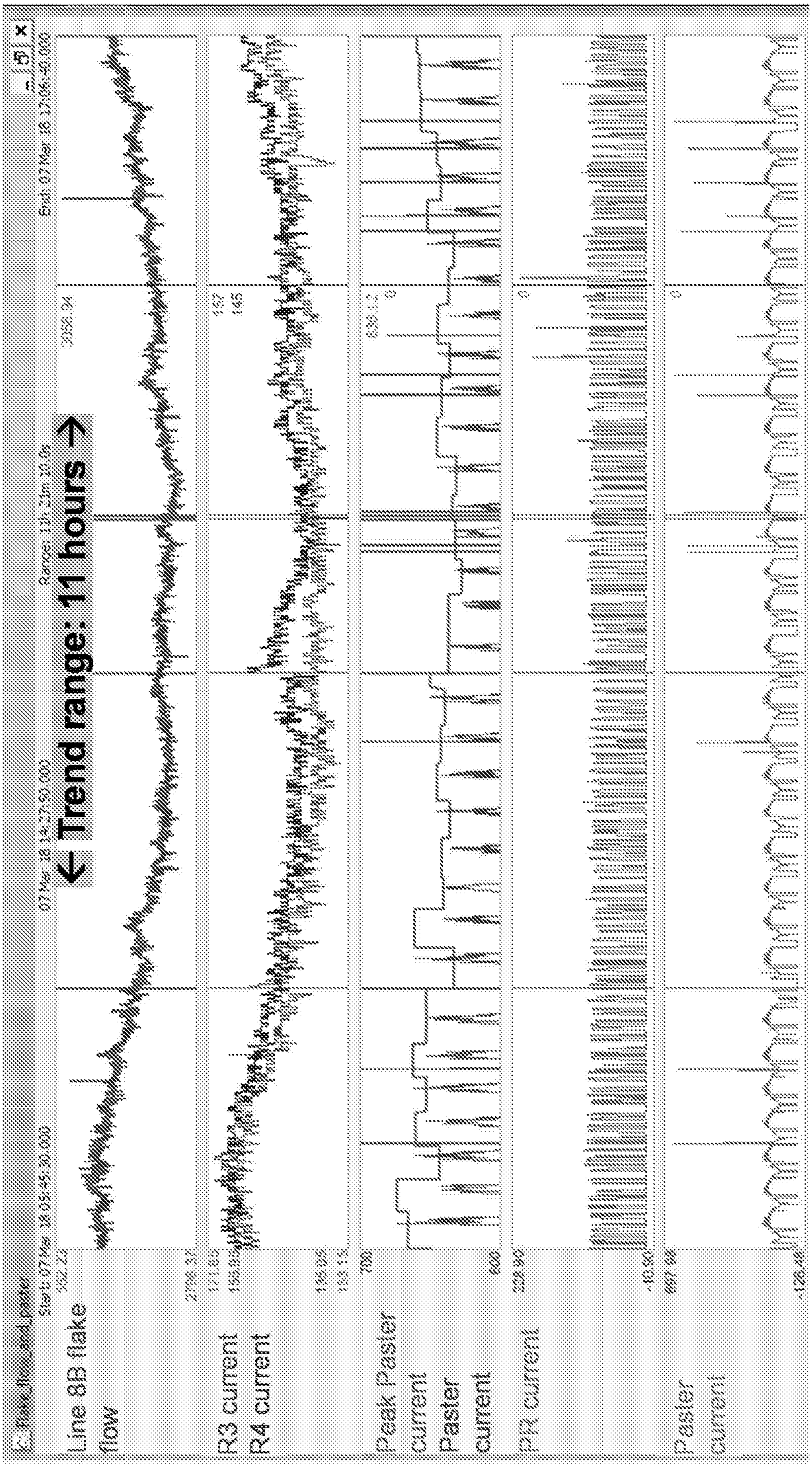

Line 8B flake flow
R3 current
R4 current
Peak Paster current
Paster current
PR current
Paster current
← Trend range: 11 hours →

Fig. 6

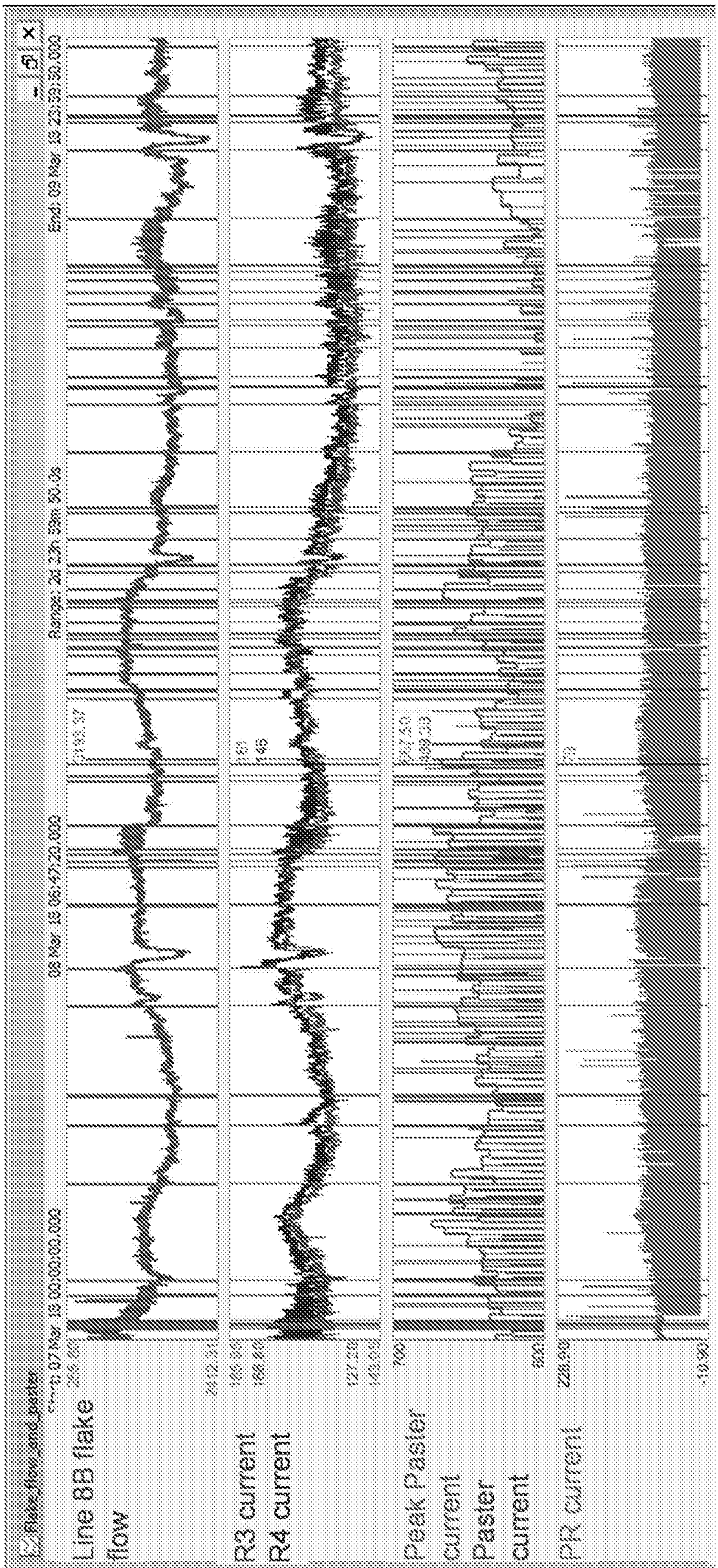

Line 8B flake flow
R3 current
R4 current
Peak Paster current
Paster current
PR current

Fig. 7

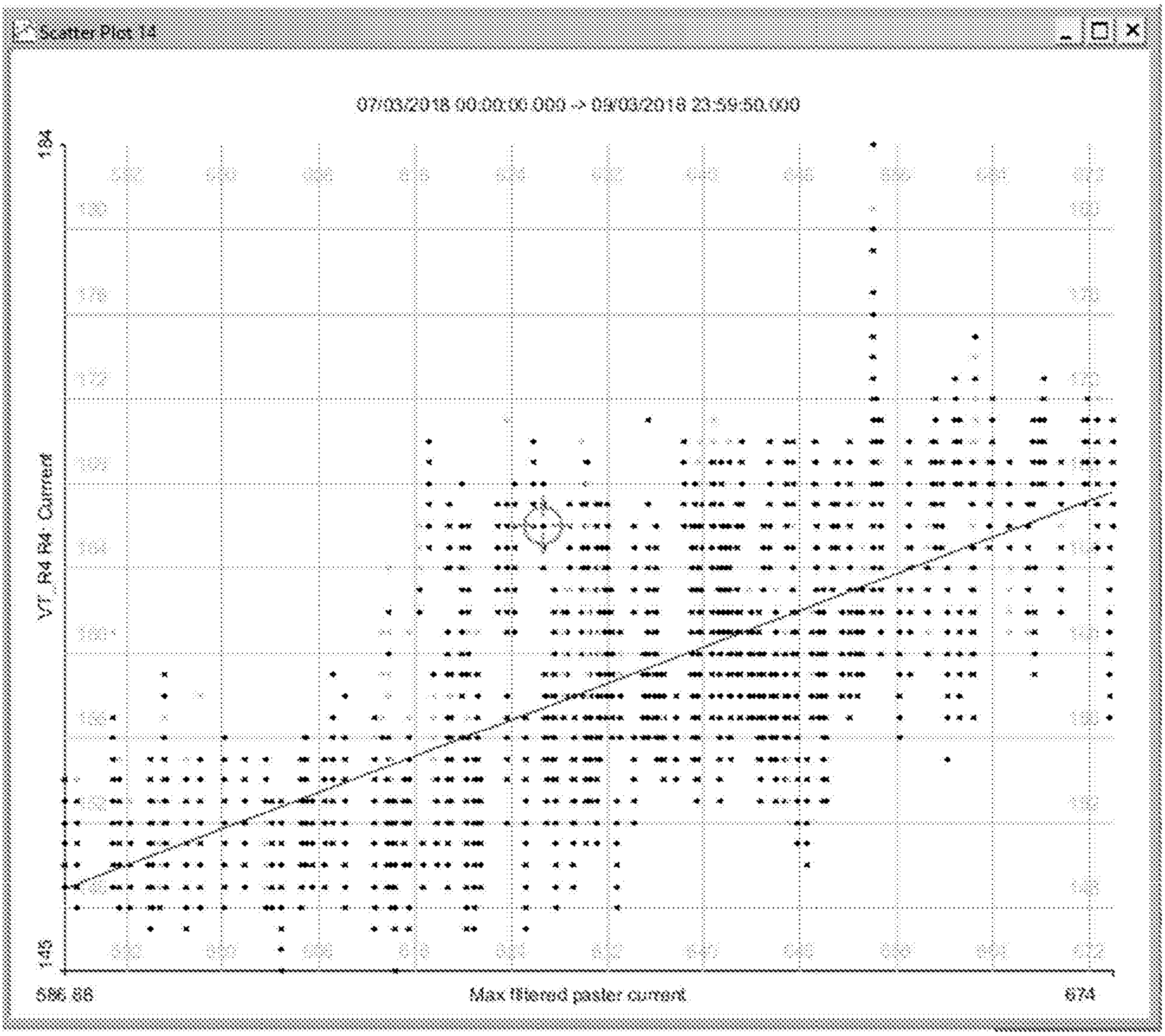

Scatter Plot 14
07/03/2018 00:00:00.000 -> 09/03/2018 23:59:50.000
184
VT_R4 R4 Current
145
596.88
Max filtered paster current
674

Fig. 8

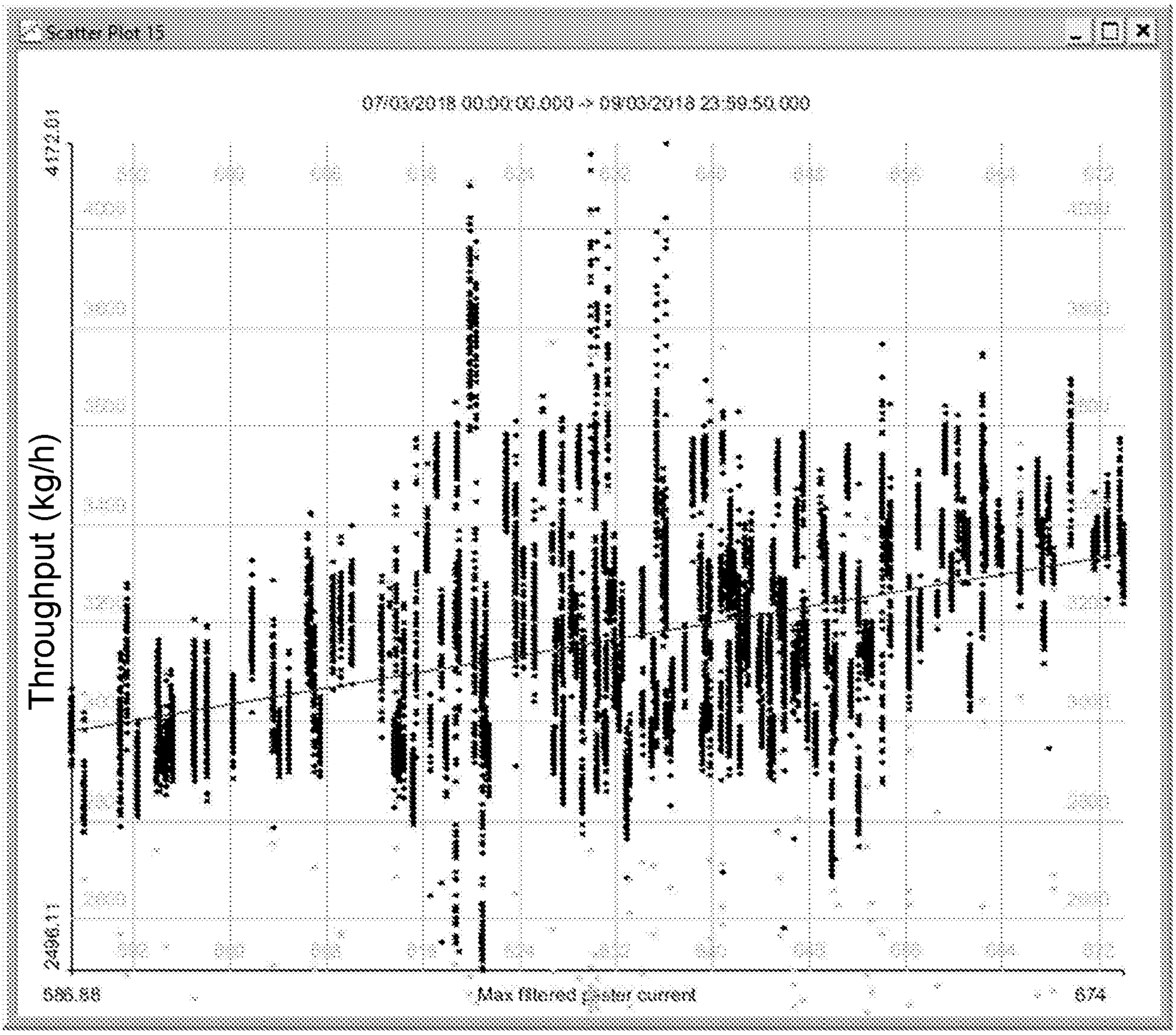

Scatter Plot 15
07/03/2018 00:00:00.000 -> 09/03/2018 23:59:50.000
Throughput (kg/h)
4172.01
2496.11
596.98
Max filtered paster current
674

Fig. 9

Apparatus and method

Field

The present invention relates to an apparatus for, and a method of, processing a confectionery product.

Background to the invention

Generally, the textural properties, for example smoothness, of confectionery products such as chocolate contribute, at least in part, to a quality thereof. Hence, for example, a goal of refining of chocolate paste, a precursor of the chocolate, is to achieve a target particle size distribution of the refined chocolate paste so as to achieve a desired smoothness. However, natural variability of the ingredients of chocolate paste may result in batch-to-batch variability of the refined chocolate paste, such that some batches fail to meet quality criteria and/or further refining is required, thereby increasing wastage and/or process inefficiency such that throughput is decreased.

Hence, there is a need to improve processing of confectionery products, for example so as to improve batch-to-batch variability while increasing throughput.

Summary of the Invention

It is one aim of the present invention, amongst others, to provide an apparatus for, and a method of, processing, at least in part, a confectionery product which at least partially obviates or mitigates at least some of the disadvantages of the prior art, whether identified herein or elsewhere. For instance, it is an aim of embodiments of the invention to provide such an apparatus and/or such a method that decreases batch-to-batch variability while increasing throughput. For instance, it is an aim of embodiments of the invention to provide such an apparatus and/or such a method that improves a quality of the confectionery product.

A first aspect provides an apparatus for processing a confectionery product, comprising:

a set of mixers, including a first mixer, for mixing one or more ingredients to provide a composition, wherein the composition is a precursor for the confectionery product; and

a set of refiners, including a first refiner, for refining the composition to provide a refined composition;

wherein the apparatus further comprises:

a set of sensors, including a first sensor configured to determine a first process output of the set of mixers and/or of the mixing; and a controller configured to control a first process input of the set of refiners based, at least in part, on the determined first process output using a control model, wherein the control model relates the determined first process output, a first target property of the set of refiners, of the refining and/or of the refined composition and the first process input of the set of refiners.

A second aspect provides a method of controlling processing of a confectionery product, comprising:
mixing one or more ingredients to provide a composition, wherein the composition is a precursor for the confectionery product; and
refining the composition to provide a refined composition;
wherein the method further comprises:
determining a first process output associated with the mixing; and
controlling a first process input for the refining based, at least in part, on the determined first process output using a control model, wherein the control model relates the determined first process output, a first target property associated with the refining and/or of the refined composition and the first process input for the refining.

A third aspect provides a tangible non-transient computer-readable storage medium having recorded thereon instructions which when implemented by a computer device including a processor and a memory, cause the computer device to perform a method according to the second aspect.

<u>Detailed Description of the Invention</u>

According to the present invention there is provided an apparatus, as set forth in the appended claims. Also provided is a method. Other features of the invention will be apparent from the dependent claims, and the description that follows.

Apparatus

The first aspect provides an apparatus for processing a confectionery product, the apparatus comprising:
a set of mixers, including a first mixer, for mixing one or more ingredients to provide a composition, wherein the composition is a precursor for the confectionery product; and
a set of refiners, including a first refiner, for refining the composition to provide a refined composition;
wherein the apparatus further comprises:
a set of sensors, including a first sensor configured to determine a first process output of the set of mixers and/or of the mixing; and

a controller configured to control a first process input of the set of refiners based, at least in part, on the determined first process output using a control model, wherein the control model relates the determined first process output, a first target property of the set of refiners, of the refining and/or of the refined composition and the first process input of the set of refiners.

In this way, the first process output of the set of mixers is fed forward to the set of refiners, which is downstream of the set of mixers, thereby enabling dynamic, proactive control of the set of refiners to thereby increase a throughput of the refined composition and/or improve the refining, for example improve a particle size distribution of particles included in the composition that are refined by the refining. In other words, responsive to monitoring of the upstream mixing, the refining is controlled, for example adjusted, accordingly, thereby accounting for variability in the ingredients, for example. In this way, batch-to-batch variability is improved because the first target property for each batch is achieved individually, thereby accounting for natural variability of the mixed ingredients. Furthermore, by improving the batch-to-batch variability to meet desired quality criteria, wastage and/or further refining is reduced and/or avoided, such that throughput is increased.

Conventional control of the refining is only reactive to assessment of the refined composition, which is thus only after the refining has been completed and hence such conventional control cannot influence and/or benefit the already refined composition. Furthermore, such conventional control is typically only manually implemented. While this conventional control may benefit a subsequent batch, for example, batch-to-batch variability of the ingredients, for example, may nullify such retrospective conventional control, which may be even contrary to the required control for the subsequent batch. Typically, to account for batch-to-batch variability of the ingredients, a predetermined excess degree of refining may be performed so as to ensure that all batches meet a desired particle size distribution, for example. In other words, the predetermined excess degree of refining accounts for expected batch-to-batch variability of ingredients, for example, and thus represents over-refining for a proportion of the batches.

In contrast, the inventors have identified that parameters of the mixing of the composition are indicators of the required refining for that particular composition, for example batch thereof. Hence, by determining such parameters (i.e. the first process output) of the mixing of that particular composition, the refining may be controlled specifically for that particular composition. In this way, refining of the particular composition to the desired particle size distribution, for example, may be performed more efficiently since the refining may be controlled appropriately for that particular composition, for example to start the refining with a larger particles and/or with smaller particles. In this way, a throughput of the refining may be increased since each composition may be refined individually to the desired particle size distribution, for example, rather than refining each composition (i.e. batch) by the predetermined degree of refining.

In one example, the apparatus is for processing a batch of the confectionery product (i.e. patch processing c.f. continuous processing).

Confectionery product

In one example, the confectionery product comprises and/or is chocolate.

Generally, a process of making chocolate comprises mixing of ingredients of the chocolate in a mixer (also known as a paster), to provide a paste (i.e. the composition) and refining (i.e. reducing) of a particle size of the paste.

The particle size of the as-mixed composition is typically in a range from about 700 to about 3000 μm and the consistency of the as-mixed composition is typically described as coarse or, as far as a semi-liquid is concerned, as having low viscosity.

Refining is typically a two-stage process including:

1. Pre-refining, in which the particle size distribution of the composition is reduced by passing the composition through a gap (also known as a nip) between rollers in a two-rolls refiner (also known as a pre-refiner). The gap is typically adjustable, for example in a range from about 100 μm to about 300 μm. The pre-refiner serves to adjust the composition's (for example the paste's) rheological properties and reduce particle size; and

2. Refining, in which the particle size distribution of the composition is then further reduced to required specification by passing the composition similarly through one or more sets of five-rolls refiners (i.e. one or more steps of refining). For example, the pre-refined composition (for example paste) is supplied to one or more five-rolls refiners, which include five pressed rolls stack having different rolls temperatures, which serve to achieve the required product fineness (i.e. particle size distribution of the refined composition) and which typically delimits a throughput of the process. In other words, this second stage of the refining is typically the rate determining step and may be thus parallelized to increase throughput.

Refining is typically the final particle size control step, before the refined composition is supplied to one or more conching units.

After (i.e. as a result of) pre-refining, the particle size distribution of the composition is typically about 250 µm or less and the pre-refined composition may be described as a semi-liquid, a paste or dough-like. After refining, the particle size is typically 30 µm or less and the refined composition (also known as flake) may be described as a powder having a fluffy structure.

Particle size distribution

It should be understood that the composition comprises particles, having a first (i.e. an initial) particle size distribution (PSD) which is modified by the refining to a second (i.e. refined) particle size distribution of the refined composition. Generally, the refining reduces a mean, a median (i.e. D50), a mode and/or another characteristic such as D90 of the first particle size distribution and/or reduces a standard deviation (SD), a variance (var) and/or a span (D90 – D10) / D50 of the first particle size distribution. In one example, the composition comprises particles having the first (i.e. initial) particle size distribution and the refined composition comprises particles having a second (i.e. refined) particle size distribution, wherein a D50, a D90, a SD, a var and/or a span of the second PSD is less than of the first PSD.

Typically, there is a target particle size for the composition after each stage of pre-refining and refining, including the one or more steps of refining. It is, moreover, desirable to achieve a low variability in the particle size and optionally, a low variability in rheological properties of the pre-refined composition. Particularly, a high variability in the particle size and optionally, the rheological properties causes variability in a quality of the final product (i.e. the confectionery) and/or reduces a yield of downstream refiners. In more detail, the particles take up fat depending on their size, physical properties and/or chemical properties. Thus, the particle size has an influence on the rheological properties of the composition. In particular, for a small particle size, a total surface area is increased such that more fat can be taken up, whereby the composition becomes "more solid" and a viscosity thereof is increased. Consequently, variations in the particle size affect the rheological properties of the composition. Thus, a low variability in particle size is desirable to attenuate variations in the rheological properties of the composition. However, even for a given particle size, the rheological properties of the composition may still vary due to differences in physical and/or chemical properties of the raw materials (i.e. the ingredients), for example from batch-to-batch due to different natural sources of the raw materials.

Particle size distributions of the composition and of the refined composition may be measured using a Mastersizer 3000 (RTM) with Hydro MV dispersion unit (Malvern Panalytical Ltd, UK), according to the manufacturer’s instructions, following ultrasonic pre-dispersion of samples thereof in an organic solvent.

Paste

In one example, the composition comprises and/or is a paste.

Generally, a paste may be defined as a mixture of a solid phase and a liquid phase or alternatively, as a dense suspension, exhibiting properties between liquid and solid. Many pastes retain their shapes against gravity, like solids. However, at high shear stresses, pastes begin to flow, thereby implying a yield stress i.e. a critical stress for transition from solid-like to fluid-like behaviour. Furthermore, most of these pastes exhibit thixotropic behaviour, such that their viscosities decreases with time, suggesting structure breakup.

Quality of chocolate

Generally, textural properties of chocolate include:

1. hardness in the mouth: the strength required to break off chocolate with the teeth and tongue;
2. meltability: the way in which chocolate melts completely in the mouth;
3. smoothness: the degree of roughness or grittiness experienced when chocolate melts in the mouth;
4. stickiness: the degree to which the mixture of melted chocolate and saliva sticks to the tongue and palate.

These textural properties contribute, at least in part, to a quality of the chocolate. Hence, by improving one or more of these textural properties, the quality of the chocolate may be, in turn, improved. For example, the smoothness and hence quality of the chocolate may be improved by refining the particle size distribution to a desired, refined particle size distribution.

Rheology of chocolate

These textural properties of chocolate are determined, at least in part, by the rheological properties and/or particle size distribution of chocolate. Hence, controlling the rheological properties and/or particle size distribution of chocolate is important in order to control, for example consistently maintain or improve, the textural properties of the chocolate. However, the rheology of chocolate is complex, as detailed below, with significant interplay between variables. Furthermore, since the raw ingredients for chocolate are sourced naturally, further variability is introduced into the process of chocolate making, for example from batch-to-batch.

Chocolate is rheologically complex both above and below its broad melting range. Chocolate shows semi-solid behaviour at room temperature (20 to 25 °C). Chocolate melts into liquid form (strictly, a dense suspension of non-colloidal particles) at temperatures very close to oral temperature that is about 30 to 32 °C. At room temperature, chocolate typically comprises about 10% liquid cocoa butter but this increases to 100% when the chocolate is fully molten above 35 °C. Generally, chocolate contains about 70% of solid sugar, some cocoa solids and crystalline cocoa butter, which are dispersed in a continuous fat-phase cocoa butter. Different commercial chocolates can be found and are categorized into three primary groups that differ in content of cocoa solids, milk, and cocoa butter: dark chocolate, milk chocolate, and white chocolate. Cocoa butter is extracted from cocoa mass (ground cocoa beans) by pressing. Cocoa butter triglyceride is mainly formed from Palmitic (P), Stearic (S), and Oleic (O) fatty acids. Due to the presence of these triglycerides, cocoa butter is forms six different crystal structures with different melting behaviours. Chocolate crystallinity is greatly influenced by temperature treatment during processing, fat content, and triglycerides type. Usually, chocolates are made by pouring or extruding melt chocolate into a mould at temperature around 30 °C and cool down to retain the desired shape.

Rheologically, ‘liquid’ chocolates demonstrate non-Newtonian behaviour with a yield stress and plastic viscosity (stress to keep fluid in motion) with mild shear-thinning characteristics. Plastic viscosity may also be known as plasticity. The rheological behaviour of chocolate is influenced by fat content, emulsifier for example lecithin and/or polyglycerol polyricinoleate (PGPR) content, water or moisture content, conching time, crystallization, particle size distribution and temperature. Generally, a lower amount of fat results in higher yield stress values and/or higher viscosities. Surfactants further influence chocolate rheology. Addition of lecithin at low concentrations (below 3 wt.%) reduces both yield stress and viscosity. At 0.1-0.3 wt.%, lecithin and optionally PGPR, has a viscosity decreasing effect similar to that achieved by adding 1-3 wt.% cocoa butter. After around 5 wt.%, addition of more lecithin increases the yield stress while the plastic viscosity of the melt continues to drop. The addition of only a (very) small quantity of water is sufficient for the plastic viscosity and yield stress to increase significantly. Particle size distribution is another important parameter, which plays a role in chocolate rheological behaviour. Particularly, the size distribution of the solid particles greatly influences the rheological properties of chocolate: the larger the particles, the lower the yield value, and also the lower the viscosity, but to a lesser extent. Cocoa particle size varies from 15 to 30 µm. A bimodal particle size distribution with a small amount of fine and large amount of coarse particles may reduce the apparent viscosity. An increase in temperature above the melting point of fat will cause the plastic viscosity to decrease but the yield stress to rise. Conching mainly affects the yield stress, which decreases considerably particularly during the first hours of conching.

Chocolate having a relatively low plastic viscosity is easier to pump while chocolate having a relatively low yield stress pours more easily into moulds.

Liquid chocolate for producing solid moulded bars typically has a plastic viscosity in a range from about 1 to about 20 Pa.s and a yield stress in a range from about 10 to about 200 Pa. Liquid chocolate for enrobings typically has a plastic viscosity in a range from about 0.5 to about 2.5 Pa.s and a yield stress in a range from about 0 to about 20 Pa.

Particle sizes of chocolate and chocolate products strongly influence the mouth feel of the chocolate product — a very small particle size produces a “smooth” sensation in the mouth. To achieve the desired quality, not only the careful testing of final products, but also the monitoring of the production process is desirable. Particularly, the presence of particles larger 30 µm is a critical quality parameter for chocolate.

Semi-solid food fats, such as chocolate mass, typically include discrete crystalline particles in a liquid fat chocolate mass. There is some loose adhesion between the crystalline particles, which breaks down rapidly when the fat a shear stress is applied. This is referred herein as plasticity. Important factors in the context of measuring plasticity include (i) content of solids; (ii) size and shape of crystalline particles; (iii) persistence of crystalline particles nuclei when changing temperature; and (iv) mechanical working of the fats. Further, a texture of the chocolate mass is governed by the measured plasticity. The quality, which is in chocolate production also referred as "tenderness" is essentially dependent upon the measured plasticity. The maximum attainable degree of tenderness is often an important attribute for the best chocolate quality. Loss of moisture decreases plasticity. Thus, quantitative measurements of plasticity can be used for control of quality, in particular in large scale chocolate production lines. Plasticity can be measured in different ways. For example, the hardness of the fat at different temperatures can be measured, e.g. using a penetrometer, such as a Humboldt penetrometer. Plasticity measurement can also be used for controlling the effectiveness of tempering in solid chocolate mass based upon measurements with a sensitive penetrometer. Other measurements can also be used to measure surface hardness. Characteristics and quality of liquid chocolate mass critically depend upon viscosity, while the texture of the solidified chocolate mass is also governed by plasticity. However, the two properties are related. Specifications for different grades of the chocolate mass during the controlling of the production cycle can include the viscosity of the liquid chocolate mass determined at temperatures somewhat above its melting point, e.g. by a viscometer.

Measurement of rheological properties

Measurement of the rheological properties of cocoa and chocolate products may be according to IOCCC (International Office of Cocoa, Chocolate, and Sugar Confectionery), “Viscosity of Cocoa and Chocolate Products (Analytical Method: 46),” CABISCO, Brussels, 2000.

Chocolate masses are melted in a water bath at 50°C and thermostated for 20 min at 40°C prior to the measurement in a rotational viscometer Model DV-III+ Digital Rheometer, Brookfield Engineering Laboratories (USA) with Spindle SC4-14, at 40°C and within the 1–50 rpm range, according to the manufacturer’s instructions. The viscometer is operated by using the Rheocalc V3.2 software which is also used for data analysis.

Rheological parameters: Casson plastic viscosity and Casson yield stress are calculated using NCA/CMA Casson model:

$$(1+a)\sqrt{\tau} = 2\sqrt{\tau_0} + (1+a)\sqrt{\mu D}$$

where:

a is spindle outer radius/measurement cup inner radius ratio;
τ is shear stress (Pa);
τ_0 is yield stress (Pa);
μ is plastic viscosity (Pa·s); and
D is shear rate (s^{-1}).

Statistical analysis is performed using software Statistica 7.0.

Different important rheological models have been used to characterize the rheological behaviour of chocolate melts including the Herschel–Bulkley, Casson, Bingham, and Carreau models. Although the Casson is the recommended model by IOCCC (International Office of Cocoa, Chocolate, and Confectionery), it has been reported that it is not able to accurately characterize chocolate melt behaviour at low shear rates and other known models may be used.

Apparatus

The apparatus is for processing the confectionery product, for example chocolate.

It should be understood that the apparatus may be suitable, more generally, for processing other products, such as paints and/or pharmaceuticals, that are similarly processed by mixing ingredients and subsequent refining. Hence, more generally, in one example, the apparatus is for processing a product, for example a confectionery product, a paint or a pharmaceutical product.

Precursor

The composition is a precursor for the confectionery product. That is, the confectionery product is derived, at least in part, from the composition. For example, the confectionery product may be produced directly from the refined composition, for example without further processing thereof. For example, the confectionery product may be produced indirectly from the refined composition, for example following further processing thereof. For example, the refined composition may be an ingredient of the confectionery product.

Set of mixers

The apparatus comprises the set of mixers, including the first mixer, for mixing one or more ingredients to provide the composition.

Generally, the ingredients are mixed for a period of time, so as to improve a homogeneity of the composition, for example by dispersing particles relatively more uniformly therein. A rheology of the mixture (i.e. the composition, for example a paste) may vary with process figures such as characteristics of the ingredients, temperature of services (for example, temperature of water for controlling mixing temperature) and/or residence time (i.e. the period of time of mixing).

In one example, the first mixer comprises and/or is a jacket mixer (also known as a jacketed mixer). Generally, jacket mixers are heated, for example by a water jacket, to a temperature in a range from 40 °C to 45 °C Other mixers are known.

In one example, the set of mixers includes a second mixer, similar to and/or the same as the first mixer. In one example, the first mixer and the second mixer are arranged mutually in series, such that the composition is mixed successively by the first mixer and the second mixer. In one example, the first mixer and the second mixer are arranged mutually in parallel, such that a first portion of the composition is mixed in the first mixer and a second portion, for example a remaining portion, of the composition is mixed in the second mixer. In one example, the set of mixers includes M mixers, including the first mixer, wherein M is a natural number greater than or equal to 1, for example 1,2, 3, 4, 5, 6, 7, 8, 9 or more. In one example, the M mixers are arranged mutually in series and/or mutually in parallel.

Ingredients

In one example, the one or more ingredients include one or more of cocoa and/or a derivative thereof for example cocoa liquor, chocolate crumb and/or cocoa butter, milk powder, fat, sugar and/or an emulsifier and any combinations of these.

Set of refiners

The set of refiners includes the first refiner and optionally a second refiner, for refining the composition to provide a refined composition.

In one example, the first refiner comprises and/or is a pre-refiner, for example a two-rolls refiner, having a controllable and/or an adjustable gap, for example in a range from about 100 µm to about 200 µm, a controllable and/or an adjustable pressure and/or a controllable and/or an adjustable speed, so as to control and/or adjust a particle size distribution of the pre-refined composition. For example, a particular gap may be provided and/or maintained by controlling a corresponding pressure, such as sufficient pressure to maintain a gap defined by a stop. For example, by increasing the speed, for example the differential speed, of the rolls, a particle size distribution of the pre-refined composition may be refined. Particularly, increasing a speed of one of the rolls, while maintaining a speed of the other rolls, will increase throughput and hence particle size. If a differential speed between rolls remains the same, the particle size will not change significantly. Differential speed control is typically used for roll stack refiners (for example 5-roll refiners). For example, the speed ratio between roll 5 and roll 2 of the 5-roll refiners is equal to the factor of particle size reduction from pre-refined paste to refiner flake. The composition after pre-refining may be known as a pre-refined composition.

In one example, the second refiner comprises and/or is a refiner, for example a three-rolls refiner or a five-rolls refiner, having 2 and 4 gaps respectively, including an adjustable gap as described with respect to the first refiner, an adjustable pressure and/or an adjustable speed. In one example, the first gap of the second refiner is an adjustable gap. In one example, one or more of the gaps of the second refiner are adjustable gaps, for example the gap between the first roller and the second roller thereof while gaps between other rollers may be fixed. In one example, the second refiner comprises a plurality N of such refiners, where N is a natural number of at least 2, for example 2, 3, 4, 5, 6, 7, 8, 9 or more. In one example, the plurality N of such refiners is arranged mutually in series and/or in parallel, such that the composition is refined successively and/or in parallel by the plurality N of such refiners. In one example, the second refiner comprises 4 five-roll refiners. It should be understood that the refined composition is thus that composition refined by the last gap of the last such refiner.

Set of sensors

The apparatus comprises the set of sensors, including the first sensor configured to determine the first process output of the set of mixers and/or of the mixing.

That is, the first sensor determines the first process output of the set of mixers and/or of the mixing.

In one example, the first sensor is communicatively coupled to the set of mixers. It should be understood that the first sensor is communicatively coupled to the controller.

In one example, the first process output of the set of mixers and/or of the mixing comprises and/or is a current, a voltage, a power, a torque, a speed and/or a pressure (i.e. sensed measurements) of the set of mixers, for example the first mixer. In one example, the set of mixers, for example the first mixer, comprises an electric motor and the current, the power, the torque, the speed and/or the pressure is of, for example drawn by or applied by, the electric motor.

Particularly, the inventors have identified that the peak paster current is an inference of a physical property, or a combination of physical properties, of the paste. For example, the physical properties may include a rheological property such as a plastic viscosity or a yield stress and/or a particle size distribution of the paste. In turn and without wishing to be bound by any theory, it is thought that differences in the physical property, or the combination of physical properties, of the paste are due, at least in part, to the particular ingredients included in a particular batch. Since the mixing is performed under controlled and relatively constant conditions from batch to batch, such as using the same mixer, the same speed of mixing and/or at the same temperature, even relatively small variations in the peak paster current from batch to batch may be attributable to the respective pastes being mixed. Hence, by monitoring the peak paster current for a particular batch, downstream refining of that particular batch may be specifically controlled accordingly so as to refine the batch to thereby provide the targeted property of the refined paste for that particular batch. It should be understood that while this description relates to peak paster current, a voltage, a power, a torque, a speed and/or a pressure of the mixing may be equivalent thereto.

More generally, the inventors have identified that the first process output of the set of mixers and/or of the mixing is an inference of a physical property, or a combination of physical properties, of the composition. For example, the physical properties may include a rheological property such as a plastic viscosity or a yield stress and/or a particle size distribution of the composition. In turn and without wishing to be bound by any theory, it is thought that differences in the physical property, or the combination of physical properties, of the paste are due, at least in part, to the particular ingredients included in a particular batch. Since the mixing is performed under controlled and relatively constant conditions from batch to batch, even relatively small variations in the first process output from batch to batch may be attributable to the respective compositions being mixed. Hence, by monitoring the first process output for a particular batch, downstream refining of that particular batch may be specifically controlled accordingly so as to refine the batch to thereby provide the targeted property of the refined composition for that particular batch.

In one example, the first process output comprises and/or is a peak (i.e. maximum) current, a peak voltage, a peak power, a peak torque, a peak speed and/or a peak pressure (i.e. sensed measurements) of the set of mixers, for example the first mixer.

In one example, the first process output comprises and/or is a moving average (i.e. maximum) current, a moving average voltage, a moving average power, a moving average torque, a moving average speed and/or a moving average pressure (i.e. sensed measurements) of the set of mixers, for example the first mixer.

In one example, the first process output comprises and/or is a peak moving average (i.e. maximum) current, a peak moving average voltage, a peak moving average power, a peak moving average torque, a peak moving average speed and/or a peak moving average pressure (i.e. sensed measurements) of the set of mixers, for example the first mixer.

In one example, the first sensor is configured to obtain, acquire, receive and/or sense a first sensed measurement (also known as an operational figure) of a set of sensed measurements for and/or of the set of mixers and/or of the mixing and to determine the first process output therefrom.

In one example, the first sensor comprises and/or is a soft-sensor (also known as a software sensor). Generally, soft-sensors are tools used for measuring one or more process or quality attributes that are calculated by software from a variety of inputs variables using statistical treatment such Partial Least Squares (PLS) or Recursive Least Squares (RLS).

In one example, the set of sensors, including the first sensor, comprises and/or is a set of soft-sensors, including the first sensor wherein the first sensor comprises and/or is a soft-sensor.

It should be understood that the set of sensors transmits (i.e. sends) the first set of process outputs of the set of mixers to the controller.

Controller

The apparatus comprises the controller configured to control the first process input of the set of refiners based, at least in part, on the determined first process output using the control model.

That is, the controller controls the refining of the composition based, at least in part, on the prior mixing of the composition, for example by controlling a gap and/or a temperature of the first refiner according to a current, such as a peak moving average current, of the first mixer. In this way, refining of a particular batch of the composition may be specific (i.e. customised, tailored) for that particular batch.

In one example, the controller comprises and/or is a computer, including at least a processor and a memory, configured to control the first process input of the set of refiners. In one example, the controller comprises and/or is a programmable logic controller (PLC), configured to control the first process input of the set of refiners. Other controllers are known.

Process inputs

In one example, the first process input of the set of refiners comprises and/or is a refining aperture, for example a nip such as an adjustable nip of refining rollers, a speed, a pressure and/or a temperature of the set of refiners, for example the first refiner . In this way, a degree of refining of the composition may be controlled by controlling the set of refiners, for example the first refiner and/or the second refiner, thereby controlling a particle size distribution of the composition.

In one example, the controller is configured to control the first process input of the set of refiners by increasing or decreasing the first process input of the set of refiners, for example within a predetermined range.

In one example, the controller is configured to control the first process input of the set of refiners continuously, intermittently, periodically and/or responsively, for example in response to the first process output transitioning outside a predetermined range.

Control model

The control model relates the determined first process output, the first target property of the set of refiners, of the refining and/or of the refined composition and the first process input of the set of refiners. For example, the control model may relate a motor current, such as a peak moving average current, of the first mixer (i.e. the first process output of first set process outputs of the set of mixers and/or of the mixing), a target physical property, or a combination of physical properties, of the composition (i.e. the first target property of the set of refiners, of the refining and/or of the refined composition) and a nip of the first refiner (i.e. the first process input of the set of refiners). Particularly, the inventors have identified that a physical property, or a combination of physical properties, of the composition may be inferred from the motor current of the set of mixers, for example the first mixer, and this can be used to define a degree of refining required so as to achieve the target particle size distribution.

In one example, the first target property of the set of refiners, of the refining and/or of the refined composition comprises and/or is a rheological property for example a plastic viscosity or a yield stress and/or a particle size distribution of the composition (i.e. combinations thereof).

For example, real-time measurement of controlled variables of the set of mixers may be passed to a Model Predictive Controller (MPC) to control the process and achieve a low variability in the chocolate mass particle size and optionally, maximize refining throughput. Generally, MPC is an advanced method of process control, where a set of constraints is satisfied and finite time-horizon optimization is achieved by predicting future events and takes control actions accordingly. Hence, at least one operational figure (i.e. first input output) of at least one two-rolls refiner (i.e. first refiner), such gap (distance between feeding rolls), and optionally, one or more operational figures of at least one five-rolls refiners (i.e. one or more second refiners), such gap and rolls temperatures, may be adjusted to predicted MPC optimal set-points to keep the process, particularly a particle size distribution of the composition within specification (i.e. target), while throughput is maximized.

In one example, the control model is developed using first process outputs previously-determined from previous compositions and first process inputs of the set of refiners previously-required for the respective previous compositions to achieve the first target property for the set of refiners, of the refining and/or of the refined composition, for example using algorithms, mathematical modelling, numerical regression such as linear and non-linear regression and/or machine learning such as using a generalized linear model (GLM), a random forest, logistic regression, a support vector machine, K-nearest neighbours, a decision tree, AdaBoost, XGBoost, a neural network for example a convolutional neural network, time-series classification, a recurrence plot, a linear mixed model, and/or an ensemble of two or more thereof.

Second sensor

In one example, the set of sensors includes a second sensor configured to determine a second process output of the set of refiners, of the refining and/or of the refined composition; and

the controller is configured to control a second process input of the set of refiners based, at least in part, on the determined second process output using the control model, wherein the control model relates the determined second process output, a second target property of the set of refiners, of the refining and/or of the refined composition and the first process input of the set of refiners.

In this way, the second process output of the set of refiners, for example, is fed back into refiners, along with the first process output of the set mixers, for example, which is fed forward to the set refiners, thereby further enabling dynamic, proactive control of the set of refiners to thereby increase a throughput of the refined composition and/or improve the refining, for example improve a particle size distribution of particles included in the composition that are refined by the refining. In other words, responsive to monitoring of the upstream mixing and the refining, the refining is controlled, for example adjusted, accordingly, thereby accounting for variability in the ingredients, for example. For example, a gap of the first refiner may be controlled based, at least in part, on a motor current of the first mixer and a motor current of the first refiner so as to achieve a target particle size distribution of the composition.

The second sensor may be generally as described with respect to the first sensor.

In one example, the second process output of the set of refiners, of the refining and/or of the refined composition comprises and/or is a physical property, or a combination of physical properties, such as a rheological property for example a plastic viscosity or a yield stress and/or a particle size distribution of the refined composition, preferably a particle size distribution of the refined composition.

In one example, the second process input of the set of refiners comprises and/or is a refining aperture, for example a nip such as an adjustable nip of refining rollers, a speed and/or a pressure of the set of refiners, for example the first refiner.

In one example, the second target property of the set of refiners, of the refining and/or of the refined composition comprises and/or is a physical property, or a combination of physical properties, such as a rheological property for example a plastic viscosity or a yield stress and/or a particle size distribution of the refined composition.

Third sensor

In one example, the set of sensors includes a third sensor configured to determine a third process output of the set of refiners, of the refining and/or of the refined composition; and the controller is configured to control a third process input of the set of refiners based, at least in part, on the determined third process output using the control model, wherein the control model relates the determined third process output, a third target property of the set of refiners, of the refining and/or of the refined composition and the third process input of the set of refiners.

In this way, the third process output of the set of refiners, for example, is fed back into refiners, along with the first process output of the set mixers, for example, which is fed forward to the set refiners, thereby further enabling dynamic, proactive control of the set of refiners to thereby increase a throughput of the refined composition and/or improve the refining, for example improve a particle size distribution of particles included in the composition that are refined by the refining. In other words, responsive to monitoring of the upstream mixing and the refining, the refining is controlled, for example adjusted, accordingly, thereby accounting for variability in the ingredients, for example. For example, a gap and/or a temperature of the first refiner may be controlled based, at least in part, on a motor current of the first mixer, a motor current of the first refiner and a throughput so as to achieve a target particle size distribution of the composition and a target throughput of the refined composition.

The third sensor may be generally as described with respect to the first sensor.

In one example, the third process output of the set of refiners, of the refining and/or of the refined composition comprises and/or is a current, a voltage, a power, a torque, a speed and/or a pressure of the set of refiners, for example the first refiner.

In one example, the third process input of the set of refiners comprises and/or is a temperature, for example a roll temperature of refining rollers, of the set of refiners, for example the first refiner.

In one example, the first target property of the third set of target properties of the set of refiners, of the refining and/or of the refined composition comprises and/or is a throughput of the refined composition.

Preferred apparatus

In one preferred example, the apparatus is for processing a batch of the confectionery product wherein the confectionery product comprises and/or is chocolate, the apparatus comprising:

the set of mixers, including the first mixer, for mixing the one or more ingredients to provide the composition, wherein the composition is a precursor for the confectionery product and wherein the composition comprises and/or is a paste; and

the set of refiners, including the first refiner and a second refiner, for refining the composition to provide the refined composition, wherein the first refiner comprises and/or is a two-rolls refiner and wherein the second refiner comprises a five-roll refiner;

wherein the apparatus further comprises:

the set of sensors, including the first sensor configured to determine the first process output of the set of mixers, wherein first sensor comprises and/or is a first soft-sensor and wherein the first process output of the set of mixers is a current, preferably a peak moving average current of an electric motor of the first mixer;

the controller configured to control the first process input of the set of refiners based, at least in part, on the determined first process output using the control model, wherein the control model relates the first process output of the set of mixers, the first target property of the set of refiners, of the refining and/or of the refined composition of the composition and the first process input of the set of refiners, wherein the first process input of the refiners comprises and/or is a gap of the first refiner and wherein the first target property of the set of refiners, of the refining and/or of the refined composition of the composition comprises and/or is a physical property, or a combination of physical properties, of the composition.

Optionally, the preferred apparatus may comprise a second sensor and/or a third sensor, as described above.

Method

The second aspect provides a method of controlling processing of a confectionery product, comprising:

mixing one or more ingredients to provide a composition, wherein the composition is a precursor for the confectionery product; and

refining the composition to provide a refined composition;

wherein the method further comprises:

determining a first process output associated with the mixing; and

controlling a first process input for the refining based, at least in part, on the determined first process output using a control model, wherein the control model relates the determined first process output, a first target property associated with the refining and/or of the refined composition and the first process input for the refining.

The controlling, the processing, the confectionery product, the mixing, the one or more ingredients, the composition, precursor, refining, refined composition, determining, first process output, first set of process outputs, the first process input, the set of process inputs, the control model, the first target property and/or the first set of target properties may be as described with respect to the first aspect.

In one example, the method is of controlling processing of a batch of the confectionery product (i.e. patch processing c.f. continuous processing).

In one example, the determined first process output comprises and/or is a current, a voltage, a power, a torque, a speed and/or a pressure of the mixing.

In one example, the first process input for the refining comprises and/or is a refining aperture, for example a nip such as an adjustable nip of refining rollers.

In one example, the first target property of the set of refiners, of the refining and/or of the refined composition comprises and/or is a physical property, or a combination of physical properties such as a rheological property for example a plastic viscosity or a yield stress and/or a particle size distribution of the composition.

In one example, the method comprises:

determining a second process output associated with the refining and/or of the refined composition; and

controlling a second process input for the refining based, at least in part, on the determined second process output using the control model, wherein the control model relates the second process output associated with the refining and/or of the refined composition, a second target property associated with the refining and/or of the refined composition and the second process input associated with the refining.

In one example, the second process output associated with the refining and/or of the refined composition comprises and/or is a current, a voltage, a power, a torque, a speed and/or a pressure associated with the refining.

In one example, the first process input associated with the refining comprises and/or is a refining aperture, for example a nip such as an adjustable nip of refining rollers, a speed and/or a pressure of the refining.

In one example, the second target property associated with the refining and/or of the refined composition comprises and/or is a physical property, or a combination of physical properties, such as a rheological property for example plastic viscosity or a yield stress and/or a particle size distribution of the refined composition.

In one example, the method comprises:
determining a third process output associated with the refining and/or of the refined composition; and
controlling a third process input of the refining based, at least in part, on the determined second process output using the control model, wherein the control model relates the third process output associated with the refining and/or of the refined composition, a third target property of the set of refiners, of the refining and/or of the refined composition and the third process input of the set of refiners.

In one example, the third process output associated with the refining and/or of the refined composition comprises and/or is a current, a voltage, a power, a torque, a speed and/or a pressure of the refining.

In one example, the second process input of the refining comprises and/or is a temperature, for example a roll temperature of refining rollers.

In one example, the first target property of the third set of target properties associated with the refining and/or of the refined composition comprises and/or is a throughput of the refined composition.

Preferred method

In one preferred example, the method is of controlling processing of a batch of the confectionery product wherein the confectionery product comprises and/or is chocolate, comprising:
mixing one or more ingredients to provide a composition, wherein the composition is a precursor for the confectionery product and wherein the composition comprises and/or is a paste; and
refining the composition to provide a refined composition, wherein the refining comprises refining using a first refiner and a second refiner, wherein the first refiner comprises and/or is a two-rolls refiner and wherein the second refiner comprises a five-roll refiner;
wherein the method further comprises:
determining the first process output of a first set of process outputs associated with the mixing, wherein the determining is by a first soft-sensor and wherein the first process output of the set

of mixers is a current, preferably a peak moving average current of an electric motor of the first mixer; and

controlling the first process input for the refining based, at least in part, on the determined first process output using the control model, wherein the control model relates the first process output associated with the mixing, the first target property of the set of refiners, of the refining and/or of the refined composition associated with the composition and the first process input for the refining, wherein the first process input of the refiners comprises and/or is a gap of the first refiner and wherein the first target property of the set of refiners, of the refining and/or of the refined composition of the composition comprises and/or is a physical property, or a combination of physical properties, of the composition.

CRM

The third aspect provides a tangible non-transient computer-readable storage medium having recorded thereon instructions which when implemented by a computer device including a processor and a memory, cause the computer device to perform a method according to the second aspect.

Definitions

Throughout this specification, the term “comprising” or “comprises” means including the component(s) specified but not to the exclusion of the presence of other components. The term “consisting essentially of” or “consists essentially of” means including the components specified but excluding other components except for materials present as impurities, unavoidable materials present as a result of processes used to provide the components, and components added for a purpose other than achieving the technical effect of the invention, such as colourants, and the like.

The term “consisting of” or “consists of” means including the components specified but excluding other components.

The optional features set out herein may be used either individually or in combination with each other where appropriate and particularly in the combinations as set out in the accompanying claims. The optional features for each aspect or exemplary embodiment of the invention, as set out herein are also applicable to all other aspects or exemplary embodiments of the invention, where appropriate. In other words, the skilled person reading this specification should consider the optional features for each aspect or exemplary embodiment of the invention as interchangeable and combinable between different aspects and exemplary embodiments.

Brief description of the drawings

For a better understanding of the invention, and to show how exemplary embodiments of the same may be brought into effect, reference will be made, by way of example only, to the accompanying diagrammatic Figures, in which:

Figure 1 schematically depicts an apparatus according to an exemplary embodiment;

Figure 2 schematically depicts a method according to an exemplary embodiment;

Figure 3 schematically depicts an apparatus according to an exemplary embodiment;

Figure 4 shows graphs of process outputs for the apparatus of Figure 3;

Figure 5 shows graphs of a process output of Figure 4, in more detail;

Figure 6 shows graphs of the process outputs of Figure 4, in more detail;

Figure 7 shows graphs of process outputs for the apparatus of Figure 3;

Figure 8 shows a graph of correlation of process outputs for the apparatus of Figure 3; and

Figure 9 shows a graph of correlation of process outputs for the apparatus of Figure 3.

Detailed Description of the Drawings

Figure 1 schematically depicts an apparatus 10 according to an exemplary embodiment. Particularly, the apparatus 10 is for processing a confectionery product.

The apparatus 10 comprises a set of mixers 100, including a first mixer 100A, for mixing one or more ingredients I to provide a composition C, wherein the composition C is a precursor for the confectionery product. The apparatus 10 comprises a set of refiners 200, including a first refiner 200A and optionally a second refiner 200B (not shown), for refining the composition C to provide a refined composition RC. The apparatus 10 comprises a set of sensors 300, including a first sensor 300A configured to determine a first process output 120A of the set of mixers 100 and/or of the mixing. The apparatus 10 comprises a controller 400 configured to control a first process input 210A of the set of refiners 200 based, at least in part, on the determined first process output 120A using a control model 500, wherein the control model

500 relates the determined first process output 120A, a first target property 210A* of the set of refiners 200, of the refining and/or of the composition C and the first process input 210A of the set of refiners 200.

The apparatus 10 may be optionally as described herein, for example with respect to the first aspect and/or adapted to implement the method as described herein, for example with respect to the second aspect.

Figure 2 schematically depicts a method according to an exemplary embodiment.

Particularly, the method is of controlling processing of a confectionery product.

At S21, one or more ingredients are mixed to provide a composition, wherein the composition is a precursor for the confectionery product.

At S22, a first process output associated with the mixing is determined.

At S23, a first process input for the refining is controlled based, at least in part, on the determined first process output using a control model, wherein the control model relates the determined first process output, a first target property associated with the refining and/or of the refined composition and the first process input for the refining.

At S24, the composition is refined to provide a refined composition.

The method may include any of the steps described herein, for example with respect to the second or the first aspect.

Figure 3 schematically depicts an apparatus 30 according to an exemplary embodiment.

Generally, the apparatus 30 is as described with respect to the apparatus 10 and like reference signs denote like features, description of which is not repeated.

Briefly, the apparatus 30 comprises the first mixer 100A and a set of refiners 200, with a first refiner 200A (particularly, a two-roll refiner i.e. a pre-refiner). The apparatus 30 further comprises the second refiner 200B, comprising N five-roll refiners: R1 to RN. The apparatus 30 comprises the first sensor 300A (particularly a soft-sensor), a second sensor 300B and a third sensor 300C communicatively coupled to the first mixer 100A, the first refiner 200A, the first second refiner 200B.R1 and the Nth second refiner 200B.RN, and to the controller 400. The first sensor 300A determines the physical property, or a combination of physical properties, of the composition C, using a measured current of the first mixer 100A (i.e. the first process output 120A of the set of mixers 100). The second sensor 300B determines the particle size distribution of the composition C, using the physical property, or a combination of physical properties, determined by the sensor 300A by using the first process output 120A of the first set of mixers 100 (sensor 300A) and a set of process inputs 210 of the set of refiners 200 (i.e. pre-refiner gap, refiner R1 and refiner RN gaps). The third sensor 300C determines the throughput of the refined composition RC, using the current of the first to Nth second refiners 200B.R1 to 200B.RN (i.e. the second process output 220B of the set of refiners 200). Using the model 500, the controller 400 controls the gap of the first refiner 200A (i.e. the first process input 210A of the set of refiners 200), as described previously. In addition, using the model 500, the controller 400 controls the respective gaps and roll temperatures of the first to Nth second refiners 200B.R1 to 200B.RN respectively, as described previously with respect to the gap of the first refiner 200A, mutatis mutandis. In this way, quality of the refined composition RC may be better maintained and/or improved, since the particle size distribution of the refined composition RC is better controlled, while the throughput increases, as described previously.

In other words, the particle size of a material (i.e. the composition) is reduced by the process to meet a quality specification and the efficiency of the process is increased, for example maximized

Particularly, the apparatus 30 includes three soft-sensors:

1. Paster soft-sensor 300A, which receives the mixer current 120A from the mixer 100A and provides the predicted paste physical property, or a combination of physical properties, to the particle size distribution (d90) soft-sensor 300B;
2. Particle size distribution (d90) soft-sensor 300B, which receives the predicted paste physical property, or a combination of physical properties, 120B from the paster soft-sensor 300A and the respective gaps of the first refiner 200A and of the first to Nth second refiners 200B.R1 to 200B.RN and provides a predicted particle size distribution to the controller 400; and
3. Refiner throughput soft-sensor 300C, which receives the refiner current 120C from the first to Nth second refiners 200B.R1 to 200B.RN and provides a predicted throughput to the controller 400.

In this context, being particle size distribution and throughput highly influenced by the physical property, or a combination of physical properties, of the processed paste, in the method of controlling, at least one operational figure of a motor associated with the paster (i.e. the first mixer 100A) is used as input in the paster soft-sensor 300A to predict the physical property, or a combination of physical properties, of paste to be refined. For example, the paster's motor current is continuously measured and the process is adjusted based on paste's predicted physical property, or a combination of physical properties.

The predicted physical property, or a combination of physical properties, is used in addition to process inputs such the first refiner 200A gap and first and Nth second refiners, 200B.R1 and 200B.RN, gaps to predict particle size distribution (Particle size soft-sensor). Similarly, at least one operational figure, such as the motor current, of at least one motor associated with at least one roller of one or more five-rolls refiners (i.e. first and Nth second refiners 200B.R1 and 200B.RN) is continuously measured and used to infer throughput (Throughout soft-sensor).

Following real-time measurement of controlled variables, as explained above, Model Predictive Controller (MPC) (i.e. the controller 400 including the model 500) is used to control the process and achieve a low variability in the confectionary mass particle size and maximize refining throughput. MPC is an advanced process control method, where a set of constraints is satisfied and optimization is achieved by predicting future events and takes respective control actions.

In this context, at least one operational figure of at least one refiner, such as gap (distance between feeding rolls), pressure, speed and/or temperature, one or more operational figures of at least one five-rolls refiners, such gap, pressure, speed and/or temperature, are adjusted to predicted MPC optimal set-points to keep process (in this case, particle size) within specification (target), while throughput is maximized.

In more detail, the apparatus 30 is for processing the confectionery product, wherein the confectionery product is chocolate. The composition C is a precursor for the confectionery product, particularly a paste. In this example, the one or more ingredients I are crumb, fats and an emulsifier. The refined composition RC is flake.

The apparatus 30 comprises the set of mixers 100, including the first mixer 100A, for mixing one or more ingredients I to provide the composition C. In this example, the first mixer 100A is a jacket mixer.

The set of refiners 200 includes the first refiner 200A and the second refiner 200B, for refining the composition C to provide a refined composition RC. In this example, the first refiner 200A is a pre-refiner, having an adjustable gap in a range from about 100 µm to about 300 µm. In this example, the second refiner 200B (R1, RN) comprises a plurality N of such refiners 200. In this example, the plurality N of such refiners 200B is arranged mutually in parallel, such that the composition C is refined in parallel by the plurality N of such refiners 200, so as to increase throughput. In this example, the second refiner 200B comprises N five-roll refiners 200.

The apparatus 30 comprises the set of sensors 300, including the first sensor 300A configured to determine the first process output 120A of the first set of process outputs 120 of the set of mixers 100 and/or of the mixing.

In this example, the first process output 120A of the set of mixers 100 is a current of the first mixer 100A. In this example, the first mixer 100A, comprises an electric motor and the current is drawn by the electric motor. In this example, the first process output 120A is a peak moving average (i.e. maximum) current of the first mixer 100A.

In this example, the first sensor 300A is a soft-sensor, labelled mixer soft sensor.

The apparatus 30 comprises the controller 400 configured to control the first process input 210A of the set of refiners 200 based, at least in part, on the determined first process output 120A of the first set of process outputs 120 using the control model 500. In this example, the controller 400 is a computer, including at least a processor and a memory, configured to control the first process input 210A of the set of refiners 200.

In this example, the first process input 210A of the set of refiners 200 is a refining aperture, particularly a nip, of the first refiner 200A.

In this example, the controller 400 is configured to control the first process input 210A of the set of refiners 200 by increasing or decreasing the first process input 210A of the set of refiners 200. In this example, the controller 400 is configured to control the first process input 210A of the set of refiners 200 continuously.

The control model 500 relates the first process output 120A of the first set of process outputs 120 of the set of mixers 100, the first target property 210A* of the first set of target properties 210* of the refined composition RC and the first process input 210A of the first set of process inputs 210 of the set of refiners 200. In this example, the control model 500 relates peak moving average current of the first mixer 100A (i.e. the first process output 120A of first set process outputs of the set of mixers 100), a target physical property, or a combination of physical properties, of the composition C (i.e. the first target property 210A* of the first set of target properties 210* of the composition C) and a nip of the first refiner 200A (i.e. the first process input 210A of the first set of process inputs 210 of the set of refiners 200).

In this example, the set of sensors 300 includes a second sensor 300B configured to determine a second process output 120B of the set of refiners 200, of the refining and/or of the refined composition RC; and the controller 400 is configured to control a second process input 210B of the set of refiners 200 based, at least in part, on the determined second process output 120B using the control model 500, wherein the control model 500 relates the determined second process output 120B, a second target property 210B* of the set of refiners 200, of the refining and/or of the refined composition RC and the second process input 210B of the set of refiners 200.

In this example, the second process output 120B of the set of refiners 200 is a gap of the second refiner 200B, a gap of the second refiner 200B.R1 and a gap of the Nth second refiner 200B.R2. In addition, the second process output 120B of the set of refiners 200 includes the predicted physical property, or a combination of physical properties, provided by the first sensor 300A. In this example, the second process input of the set of refiners 200 is the gap and a temperature of the second refiner 200B, the gap and a temperature of the second refiner 200B.R1 and the gap and a temperature of the Nth second refiner 200B.R2. In this example, the second target property 210B* of the set of refiners 200 is a particle size distribution, particularly D90, of the refined composition RC.

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In this example, the set of sensors 300 includes a third sensor 300C configured to determine a third process output 120C of the set of refiners 200, of the refining and/or of the refined composition RC; and
the controller 400 is configured to control a third process input of the set of refiners 200 based, at least in part, on the determined third process output 120C using the control model 500, wherein the control model 500 relates the determined first process output 120C, a third target property 210C* of the set of refiners 200, of the refining and/or of the refined composition RC and the third process input of the set of refiners 200.

In this example, the third process output 120C of the set of refiners 200 is the refiner current 120C from the first to Nth second refiners 200B.R1 to 200B.RN. In this example, the third process input of the set of refiners 200 is the second process input of the set of refiners 200 is the gap and a temperature of the second refiner 200B, the gap and a temperature of the second refiner 200B.R1 and the gap and a temperature of the Nth second refiner 200B.R2. In this example, the third target property 210A* of the set of refiners 200 is a target throughput of the refined composition RC.

Figure 4 shows graphs of process outputs for the apparatus of Figure 3.

Particularly, Figure 4 shows graphs, as a function of time during about 1.5 hours of processing of 5 batch cycles, of:

A. throughput of the refined composition (kg/h) (referred to as Line 8A flake flow and Line 8B flake flow);
B. refiner R1 current (A) (referred to as R3 current (A)) and refiner RN current (A) (referred to as R4 current (A));
C. pre-refiner current (A) (referred to as PR current); and
D. paster current (A).

The refiner R1 and the refiner RN were operational throughout the processing. The gaps for the pre-refiner, the refiner R1 and the refiner RN are maintained constant throughout the processing. The batch cycles appear consistent.

Figure 5 shows graphs of a process output of Figure 4, in more detail;

Particularly, Figure 5 shows graphs, as a function of time during about 1.5 hours of processing, of:

A. paster current (A);
B. paster current (A) (40 s moving average); and
C. paster current (A) (peak value of 40 s moving average).

Figure 6 shows graphs of the process outputs of Figure 4, in more detail;

Particularly, Figure 6 shows graphs, as a function of time during about 11.5 hours of processing, of:

A. throughput of the refined composition (kg/h) (referred to as Line 8B flake flow);
B. refiner R1 current (A) (referred to R3 current (A)) and refiner RN current (A) (referred to as R4 current (A));
C. peak paster current (A) and paster current (A);
D. pre-refiner current (A) (referred to as PR current); and
E. paster current (A).

The refiner R1 and the refiner RN were operational throughout the processing. The gaps for the pre-refiner, the refiner R1 and the refiner RN are maintained constant throughout the processing. The peak paster current is the peak value of 40 s moving average paster current.

Correlation between the peak paster current, the refiner R1 current, the refiner RN current and the throughput of the refined composition is apparent from visual inspection. Particularly, local

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maxima and local minima in the peak paster current, the refiner R1 current, the refiner RN current and the throughput of the refined composition are temporally aligned.

Particularly, there is a clear correlation between the peak paster current and flake flow (i.e. the throughput of the refined composition):

1. peak paster current is an inference of a paste physical property, or a combination of physical properties; and
2. for a given set of running conditions (i.e. refiners on/off and gap sizes in pre-refiner, refiner R1, and refiner RN), there is a clear correlation of peak paster current with flake flow.

Figure 7 shows graphs of process outputs for the apparatus of Figure 3.

Particularly, Figure 7 shows graphs, as a function of time during 72 hours of processing, of:

A. throughput of the refined composition (kg/h) (referred to as Line 8B flake flow);
B. refiner R1 current (A) (referred to as R3 current (A)) and refiner RN current (A) (referred to as R4 current (A));
C. peak paster current (A) and paster current (A); and
D. pre-refiner current (A) (referred to as PR current).

The refiner R1 and the refiner RN were operational throughout the processing. The gaps for the pre-refiner, the refiner R1 and the refiner RN are maintained constant throughout the processing. The peak paster current is the peak value of 40 s moving average paster current.

Correlation between the peak paster current, the refiner R1 current, the refiner RN current and the throughput of the refined composition is apparent from visual inspection. Particularly, local maxima and local minima in the peak paster current, the refiner R1 current, the refiner RN current and the throughput of the refined composition are temporally aligned.

Figure 8 shows a graph of correlation of process outputs for the apparatus of Figure 3.

Particularly, Figure 8 shows a scatter chart of refiner RN current (referred to as VT_R4 R4: Current) of the composition as a function of peak paster current (A) (referred to as max filtered paster current), during 72 hours of processing. The throughput of the refined composition varied between about 2500 kg/h and about 4200 kg/h. The peak paster current varied between about 590 A and about 675 A.

The linear line of best fit has a product moment correlation coefficient of 0.71, which is good, thereby demonstrating the relationship between the refiner RN current and the peak paster current.

Figure 9 shows a graph of correlation of process outputs for the apparatus of Figure 3.

Particularly, Figure 9 shows a scatter chart of throughput (kg/h) (also known as continuous flake flow measurement) of the refined composition as a function of peak paster current (A) (referred to as max filtered paster current), during 72 hours of processing. The throughput of the refined composition varied between about 2500 kg/h and about 4200 kg/h. The peak paster current varied between about 590 A and about 675 A.

The linear line of best fit has a product moment correlation coefficient of 0.40, thereby on the threshold of indicating a relationship. However, given the batch-to-batch nature of the throughput of the refined composition versus the peak paster current, it is expected that the mathematical correlation will be less strong.

Although a preferred embodiment has been shown and described, it will be appreciated by those skilled in the art that various changes and modifications might be made without departing from the scope of the invention, as defined in the appended claims and as described above.

In summary, the invention provides an apparatus for, and a method of, processing a confectionery product that increases a throughput of the process while improving a quality of the confectionery product.

All of the features disclosed in this specification (including any accompanying claims and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at most some of such features and/or steps are mutually exclusive.

Each feature disclosed in this specification (including any accompanying claims, and drawings) may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

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CLAIMS

1. An apparatus for processing a confectionery product, the apparatus comprising:

a set of mixers, including a first mixer, for mixing one or more ingredients to provide a composition, wherein the composition is a precursor for the confectionery product; and

a set of refiners, including a first refiner, for refining the composition to provide a refined composition;

wherein the apparatus further comprises:

a set of sensors, including a first sensor configured to determine a first process output of the set of mixers and/or of the mixing; and

a controller configured to control a first process input of the set of refiners based, at least in part, on the determined first process output using a control model, wherein the control model relates the determined first process output, a first target property of the set of refiners, of the refining and/or of the refined composition and the first process input of the set of refiners.

2. The apparatus according to claim 1, wherein the first process output of the set of mixers and/or of the mixing comprises and/or is a current, a voltage, a power, a torque, a speed and/or a pressure of the set of mixers.

3. The apparatus according to any previous claim, wherein the first process input of the set of refiners comprises and/or is a refining aperture a speed, a pressure and/or a temperature of the set of refiners.

4. The apparatus according to any previous claim, wherein the first target property of the set of refiners, of the refining and/or of the refined composition comprises and/or is physical property, or a combination of physical properties, of the composition.

5. The apparatus according to any previous claim,

wherein the set of sensors includes a second sensor configured to determine a second process output of the set of refiners, of the refining and/or of the refined composition; and

wherein the controller is configured to control a second process input of the set of refiners based, at least in part, on the determined second process output using the control model, wherein the control model relates the determined second process output, a second target property of the set of refiners, of the refining and/or of the refined composition and the first process input of the set of refiners.

6. The apparatus according to claim 5, wherein the second process output of the set of refiners, of the refining and/or of the refined composition comprises and/or is a physical property, or a combination of physical properties, of the refined composition.

7. The apparatus according to claim 6, wherein the physical property, or the combination of physical properties of the refined composition, is a predicted physical property, or a combination of predicted physical properties, of the refined composition.

8. The apparatus according to claim 7, wherein the controller is configured to predict the first target property using the determined first process output.

9. The apparatus according to any of claims 5 to 8, wherein the second process input of the set of refiners comprises and/or is a refining aperture, a speed, a pressure and/or a temperature of the set of refiners.

10. The apparatus according to any of claims 5 to 9, wherein the second target property of the set of refiners, of the refining and/or of the refined composition comprises and/or is a physical property, or a combination of physical properties, of the refined composition.

11. The apparatus according to any previous claim, wherein the set of sensors includes a third sensor configured to determine a third process output of the set of refiners, of the refining and/or of the refined composition; and
wherein the controller is configured to control a third process input of the set of refiners based, at least in part, on the determined third process output using the control model, wherein the control model relates the determined third process output, a third target property of the set of refiners, of the refining and/or of the refined composition and the third process input of the set of refiners.

12. The apparatus according to claim 11, wherein the third process output of the set of refiners, of the refining and/or of the refined composition comprises and/or is a current, a voltage, a power, a torque, a speed and/or a pressure of the set of refiners.

13. The apparatus according to any of claims 11 to 12, wherein the third process input of the set of refiners comprises and/or is a temperature of the set of refiners.

14. The apparatus according to any of claims 11 to 13, wherein the first target property of the third set of target properties of the set of refiners, of the refining and/or of the refined composition comprises and/or is a throughput of the refined composition.

15. The apparatus according to any previous claim, wherein the first sensor comprises and/or is a soft sensor.

16. A method of controlling processing of a confectionery product, comprising:
mixing one or more ingredients to provide a composition, wherein the composition is a precursor for the confectionery product; and
refining the composition to provide a refined composition;
wherein the method further comprises:
determining a first process output associated with the mixing; and
controlling a first process input for the refining based, at least in part, on the determined first process output using a control model, wherein the control model relates the determined first process output, a first target property associated with the refining and/or of the refined composition and the first process input for the refining.

17. The method according to claim 16, wherein the first process output associated with the mixing comprises and/or is a current, a voltage, a power, a torque, a speed and/or a pressure of the mixing.

18. The method according to any of claims 16 to 17, wherein the first process input for the refining comprises and/or is a refining aperture.

19. The method according to any of claims 16 to 18, wherein the first target property of the set of refiners, of the refining and/or of the refined composition comprises and/or is a physical property, or a combination of physical properties, of the refined composition.

20. The method according to any of claims 16 to 19, wherein the physical property, or the combination of physical properties of the refined composition, is a predicted physical property, or a combination of predicted physical properties, of the refined composition.

21. The method according to claim 19, comprising predicting the first target property using the determined first process output.

22. The method according to any of claims 16 to 21, comprising:
determining a second process output associated with the refining and/or of the refined composition; and
controlling a second process input for the refining based, at least in part, on the determined second process output using the control model, wherein the control model relates the second process output associated with the refining and/or of the refined composition, a second target property associated with the refining and/or of the refined composition and the second process input associated with the refining.

23. The method according to any of claims 16 to 22, comprising:

determining a third process output associated with the refining and/or of the refined composition; and

controlling a third process input of the refining based, at least in part, on the determined third process output using the control model, wherein the control model relates the determined third process output, a third target property of the set of refiners, of the refining and/or of the refined composition and the second process input of the set of refiners.

24. The method according to any of claims 16 to 23, wherein determining the first process output is by a first soft-sensor.

25. A tangible non-transient computer-readable storage medium having recorded thereon instructions which when implemented by a computer device including a processor and a memory, cause the computer device to perform a method of any of claims 16 to 24.