

SWEETENER FORMULATIONS

FIELD AND BACKGROUND OF THE INVENTION

The present invention relates to sweet formulations containing silica within the sweetener particles.

SUMMARY OF THE INVENTION

According to teachings of the present invention there is provided a formulation including a first population of sweetener particles, each individual sweetener particle containing sweetener particles containing a caloric sweetener; and a plurality of amorphous silica particles, disposed in each individual sweetener particle; wherein the average ratio of the number of the amorphous silica particles to the number of the sweetener particles is at least 2.5:1, wherein the first population of sweetener particles is less sweet with respect to a control sweetener identical to the first population of sweetener particles, but devoid of the plurality of amorphous silica particles, and wherein, when the first population is diluted with sucrose to produce a standard formulation containing 0.1% amorphous silica, the standard formulation exhibits improved sweetness with respect to a corresponding control sucrose formulation identical to the standard formulation, but devoid of the plurality of amorphous silica particles.

Additional aspects and embodiments of the present invention will be evident from the detailed description provided hereinbelow.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention, the description taken with the drawings making apparent to those skilled in the art how the several forms of the invention may be embodied in practice.

In the drawings:

Figure 1 is a block diagram of a method of producing silica-and-sweetener particles, according to embodiments of the present invention;

Figure 2 is a schematic representation of a slurry of sweetener particles and silica particles disposed in a concentrated sweetener solution, according to embodiments of the

methods of the present invention;

Figure 3 is a schematic representation of an exemplary crystallizer for effecting step 104, according to embodiments of the inventive method;

Figure 4 is a schematic representation of a silica-and-sweetener coated sweetener particle (*e.g.*, a coated sugar particle) according to embodiments of the present invention;

Figure 5 is a schematic representation of a silica-and-sweetener coated sweetener particle consisting of a core having a radius or characteristic radius R_{core} , the core enveloped or at least partially enveloped by a shell;

Figure 6A is a graph displaying the comparative dissolution kinetics of sucrose formulations containing low concentrations of amorphous silica vs. a crystalline sucrose control formulation;

Figure 6B is a graph displaying the comparative dissolution kinetics of a sucrose sweetener concentrate according to the present invention vs. a crystalline sucrose control formulation;

Figure 7 provides X-ray diffraction (XRD) plots displaying the crystalline character of various sweetener-and-silica sweetener concentrate formulations, according to embodiments of the present invention;

Figure 8 is a schematic, magnified representation of a sweetener formulation containing silica-and-sweetener coated sweetener particles diluted with ordinary sweetener particles, according to aspects of the present invention; and

Figure 9 is a photograph of an inventive muffin vs. two types of control muffin.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present disclosure describes improved sweetener formulations and methods for making such improved sweetener formulations and utilizing them in food products.

The present disclosure describes sweetener-and-silica sweetener formulations and methods for making such formulations and for utilizing them in food products. In some embodiments, the formulations may include a sweetener kernel including at least one of a sweetener carbohydrate (*e.g.*, sucrose) and a sweetener polyol. The coating enveloping the kernel includes amorphous silica and a sweetener – typically sugar.

The use of amorphous silica to enhance the sweetness of sugar is known: the amorphous silica serves as a carrier for the sugar, which forms on the surface of the amorphous silica as amorphous sugar.

In water, amorphous sugar is known to have improved dissolution kinetics with respect to crystalline sugar. During eating, the amount of sugar that dissolves in the mouth will be higher

for amorphous sugar with respect to its corresponding crystalline sugar.

The sweetener-and-silica sweetener particles in the formulations of the present invention exhibit dissolution kinetics that may be -- disadvantageously -- appreciably lower than the dissolution kinetics of the corresponding amorphous sweetener. The sweetener-and-silica sweetener particles in the formulations of the present invention may even exhibit dissolution kinetics that are appreciably lower than the dissolution kinetics of the corresponding, fully-crystalline sweetener.

Not surprisingly, the perceived sweetness of such sweetener-and-silica sweetener particles may be significantly reduced with respect to a control sweetener formulation that is identical to the sweet formulation, but devoid of the amorphous silica.

This deficiency notwithstanding, the inventors have surprisingly discovered that when disposed in a formulation containing one or more types of ordinary sweetener particles (e.g., table sugar), such sweetness-compromised sweetener-and-silica sweetener particles may actually enhance the perceived sweetness of the formulation as a whole. For example, when the sweetener-and-silica sweetener particles is “diluted” with table sugar and utilized within a food product such as a confection or sweet baked goods (cakes, cookies, pastries, and the like), this food product may exhibit appreciably improved sweetness with respect to a control food product having the identical concentration of sweetener (in this example: ordinary sugar), but devoid of the amorphous silica.

Alternatively, the inventive food product may be formulated to contain appreciably less caloric sweetener (e.g., 20% to 50% less) than a corresponding conventional food product, with no reduction in perceived sweetness.

In addition to the manifest health benefits, the use of sweetness-compromised sweetener-and-silica sweetener particles diluted by ordinary sweeteners such as ordinary, crystalline sugar may lead to appreciably reduced production costs for the various food products, with respect to sweetener-and-silica sweetener formulations in which essentially all of the sweetener particles contain silica at low concentration.

With reference now to the Figures, Figure 1 is a block diagram of a method of producing silica-and-sweetener containing particles, according to embodiments of the present invention. Step 102 of the method includes providing a slurry containing solids disposed in an aqueous medium containing dissolved sweetener, the solids including silica particles and sweetener kernel particles such as sucrose.

In some embodiments, step 102 of the method may include contacting sweetener particles with an aqueous medium containing dissolved sweetener and silica particles, to produce a slurry containing sweetener kernel particles and silica particles in a sweetener solution (“concentrated

sweetener solution” or “concentrated sugar solution”).

Figure 2 provides a schematic representation of such a slurry 200, in which sweetener kernel particles 202 and silica particles 204 are in contact with an aqueous sweetener solution 206. It will be appreciated that aqueous sweetener solution 206 may be saturated or substantially saturated with respect to the sweetener.

While typically, the sweetener is a sugar, such as sucrose, in the general process description provided below, the term “sugar” is meant to refer to the more general case, *i.e.*, a “caloric sweetener”.

As used herein, the term “caloric sweetener” refers to at least one sweetener selected from the group consisting of a sweetener carbohydrate (*e.g.*, sucrose) and a sweetener polyol (*e.g.*, maltitol).

Step 104 of the method may include depositing at least a portion of the dissolved sweetener in the aqueous medium onto the sweetener kernel particles to produce a sweetener coating enveloping the sweetener kernel particles, the sweetener coating including at least a portion of the silica particles. Step 104, which is optional, may be performed in a crystallizer, such as a cooling crystallizer, a flash-cooling crystallizer, or an evaporative crystallizer. Forced circulation crystallizers, draft-tube crystallizers, Oslo-type crystallizers, and other types of crystallizers may be employed. The supersaturation with respect to the sweetener may result in the precipitation of sweetener as crystals (*e.g.*, by secondary nucleation), and/or onto the surface of the amorphous silica.

Step 106 of the method includes optionally separating off a first portion of the aqueous medium (*e.g.*, from step 102 or step 104) and a first portion of the silica particles from the sugar kernel particles. As a result, a wet cake may be produced, in which a second portion of the aqueous medium and a second portion of the silica particles may be disposed around the sugar kernel particles.

Step 108 of the method includes optionally drying at least a portion of the sweetener product or at least a portion of the solids (*e.g.*, from any of step 102, step 104, and/or step 106) to produce a dried sweetener product containing a high concentration of amorphous silica (“silica and sweetener concentrate”). This concentrate may also contain coated sweetener particles having a silica-and-sweetener coating enveloping the sweetener kernel particles. The sugar-and-silica coating may include silica particles from the second portion of the silica particles.

Both batch processing and continuous processing may be utilized in the inventive method.

Figure 3 is a schematic representation of an exemplary crystallizer for effecting step 104 according to embodiments of the inventive method.

Figure 4 is a schematic representation of a coated sweetener particle according to embodiments of the present invention. In this embodiment, the coated sweetener particle consists of a central kernel having a radius or characteristic radius R_{kernel} , the core enveloped or at least partially enveloped by a coating having a characteristic thickness T_{coating} . Since the kernel is typically a pure sugar or sweetener, the kernel may be (*i.e.*, is typically) devoid or substantially devoid of silica. It is manifest that the average weight concentration of silica within the coating, $C_{\text{SIL-coating}}$, is greater than the average weight concentration of silica within the kernel, $C_{\text{SIL-kernel}}$:

$$C_{\text{SIL-coating}} > C_{\text{SIL-kernel}}$$

The ratio $C_{\text{SIL-kernel}} / C_{\text{SIL-coating}}$ may be at most 0.2, and more typically, at most 0.1, at most 0.05, or at most 0.02. Most typically, $C_{\text{SIL-kernel}} / C_{\text{SIL-coating}}$ may be 0 or substantially 0.

It will be appreciated by those of skill in the art that various analytical techniques may be used to characterize the outer layer or coating of the coated sweetener particles, and to compare the characteristics with those of the material underlying the coating.

In some embodiments, the silica utilized in accordance with the present invention is an amorphous silica in which the average particle size (D_{v50-S}) is within a range of 0.8 to 20 micrometers (μm).

In some embodiments, D_{v50-S} is at least 1.5mm, at least 2mm, at least 2.5mm, or at least 3mm, at least 5mm, at least 6mm, or at least 7mm.

In some embodiments, D_{v50-S} is at most 18mm, at most 16mm, at most 14mm, or at most 12mm.

In some embodiments, D_{v50-S} is within a range of 1.5 to 20mm, 2 to 20mm, 3 to 20mm, 4 to 20mm, 5 to 20mm, 6 to 20mm, 7 to 20mm, 1.5 to 15mm, 2.5 to 15mm, or 3 to 15mm.

With reference now to Figure 5, Figure 5 is a schematic representation of a spherical sweetener particle consisting of a core having a radius or characteristic radius R_{core} , the core enveloped or at least partially enveloped by a shell having a thickness T_{shell} . As described hereinabove, the etching process (such as that described in Example 26 hereinbelow) may be performed so as to remove a portion of the shell without dissolving any (or very little) of the core. Alternatively, the etching process may be designed to remove substantially all of the shell, while dissolving only a portion or relatively small portion of the core.

As used herein in the Specification and claims, the term “standard etching process” refers to an etching process that removes, on average, 10 micrometers of the coated sweetener particles. The value of 10 micrometers is calculated based on a spherical model for the particles, as shown in Figure 5. The model further assumes that the sweetener particles all have the size of D_{v50} , the particle volume averaged size of the population.

Since the kernel is typically a pure sugar or sweetener, the “core” may be (*i.e.*, is typically) devoid or substantially devoid of silica. It is manifest that the average (weight) concentration of silica within the coating, $C_{\text{SIL-shell}}$, is greater than the average (weight) concentration of silica within the core, $C_{\text{SIL-core}}$:

$$C_{\text{SIL-shell}} > C_{\text{SIL-core}}$$

The ratio $C_{\text{SIL-shell}} > C_{\text{SIL-core}}$ may be at most 0.2, and more typically, at most 0.1, at most 0.05, or at most 0.02. Most typically, $C_{\text{SIL-shell}} > C_{\text{SIL-core}}$ may be 0 or substantially 0. As above, these concentrations are calculated on a sweetener + silica basis.

It will be appreciated by those of skill in the art that various analytical techniques may be used to characterize the outer shell of the coated sweetener particles, and to compare the characteristics with those of the material in the core underlying the coating.

Figure 6A is a graph displaying the comparative dissolution kinetics of sucrose formulations containing low concentrations of amorphous silica vs. a corresponding crystalline sucrose control formulation. The concentration of dissolved sweetener (sucrose) is plotted as a function of dissolution time. The experimental conditions are provided in Example 94 hereinbelow.

It is evident from Figure 6A that the pure crystalline sucrose exhibits the slowest dissolution kinetics. All three of the sucrose samples containing amorphous silica exhibit faster dissolution kinetics, with the kinetics monotonically increasing with increasing concentration of amorphous silica. After 30 seconds, which may be the most significant period of time for foods that are chewed and tasted, the dissolution kinetics for the sample containing 1% amorphous silica exceeded the kinetics for the pure crystalline sucrose sample by over 25%.

Figure 6B is a graph displaying the comparative dissolution kinetics of a sweetener concentrate according to the present invention, containing 50% sucrose and 50% amorphous silica vs. a corresponding crystalline sucrose control formulation. The concentration of dissolved sweetener (sucrose) is plotted as a function of dissolution time. The experimental conditions are provided in Example 95 hereinbelow.

It is evident from Figure 6B that the sweetener concentrate according to the present invention exhibits appreciably slower dissolution kinetics than the sucrose control formulation. This is surprising, given that the sucrose control formulation is fully crystalline. It is yet further surprising in view of the results shown in Figure 6A, in which all the sweetener concentrates containing amorphous silica achieve faster dissolution kinetics with respect to the same sucrose control formulation utilized in Example 95.

Figure 7 provides X-ray diffraction (XRD) plots displaying the crystalline character of various sweetener-and-silica sweetener concentrate formulations, according to embodiments of

the present invention. It is apparent from the XRD plots that the various sweetener (sucrose) samples are crystalline or exhibit crystalline behavior, even at relatively high concentrations of amorphous silica. The inventors have found that such crystalline behavior may be observed up to amorphous silica concentrations of 50% or more.

Figure 8 is a schematic, magnified representation of a sweetener formulation 600 containing silica-and-sweetener coated sweetener particles 602 diluted with or blended with sweetener particles 604 such as ordinary sweetener particles (e.g., crystalline sucrose), according to aspects of the present invention.

This advantageously allows for the use of ordinary, conventional and inexpensive sweetener materials (e.g., a crystalline sucrose product such as table sugar) as the predominant component of the inventive sweetener formulation. By way of example, for a diluted sweetener formulation having a final silica concentration of 0.2%, and using a caloric sweetener concentrate containing 50% caloric sweetener and 50% amorphous silica, one ton of the inventive, diluted formulation requires 2kg of amorphous silica (i.e., 4 kg of the sweetener concentrate), yielding 996 kg as the requirement for the ordinary sweetener such as table sugar. As a second example, for a diluted sweetener formulation having a final silica concentration of 0.4%, and using a caloric sweetener concentrate containing 84% caloric sweetener and 16% amorphous silica, one ton of the inventive, diluted formulation requires 4 kg of amorphous silica (i.e., 25 kg of the sweetener concentrate -- $[100\%/16\%] \cdot 4$), yielding 975 kg as the requirement for the ordinary sweetener such as table sugar.

The concentration of amorphous silica in the diluted sweetener formulation is typically 0.05%-2%. The concentration of amorphous silica in the food product (e.g., confections, sweet baked goods) is typically 0.003%-1%.

Figure 9 is a photograph showing an inventive muffin vs. two types of control muffin. The muffins on the left ("Inventive Formulation") and on the right ("Control II") were prepared according to Examples 82 and 82A provided hereinbelow. The muffin in the center ("Control I") contained the identical silica-and-sugar concentrate as the inventive formulation, and the identical concentration of sugar as the inventive formulation. However, instead of diluting with ordinary sugar as in the inventive formulation, the entire amount of sugar was provided by the silica-and-sugar concentrate.

The texture of the inventive muffin was found to be advantageously similar to the superior texture of the conventional, full-sugar (crystalline sucrose) muffin.

With regard to the sweetness of the muffins, the control I muffin containing the undiluted silica-sucrose concentrate (~ 40% reduced sugar) was found to be appreciably less sweet than both the full-sugar control II muffin and the inventive muffin containing the diluted silica-

sucrose concentrate (~40% reduced sugar), which were found to be of comparable sweetness.

EXAMPLES

Reference is now made to the following examples, which together with the above descriptions, illustrate the invention in a non-limiting fashion.

List of Equipment Used:

Instruments	Manufacturer	Model	Measuring range	Units
High shear mixer	IKA	IKA T 25 ULTRA-TURRAX®	3000-25000	rpm
	Silverson	L5M-A	0-8000	rpm
Vacuum mixer-dryer (cooking mixer)	Stephan	UMC 5	300-3000	1/min
Vacuum pump	Vacuubrand	MZ 2C NT	50	Hz
Laboratory oven (Thermomix®)	MRC Ltd	DFO-150	25-250	°C
Ultra centrifugal mill	Retsch	ZM200	50	Hz
Pocket Refractometer	ATAGO	PAL-BX/RI	0.0-93.0	%

List of Materials Used:

Material	Manufacturer	Type	Average Particle Size (micrometers)	Specific Surface Area (m ² /g)
Silica	Grace	Grace Syloid® 9005	4.5 - 5.3	300
	Flo-gard™	T-700	4	
		T-800	2.5	
		915		
		233		
Inulin	Beneo	Orafti Highly Soluble Inulin		
	Cosucra	Fibruline		
	Sensus	Frutafit CLR		
Sugar	Sugat®	White sugar EU 2	400-1000	0.009

EXAMPLE 1

A concentrated sugar syrup, typically containing about 60 to 75wt% sugar, is prepared, typically at around 60°C to 70°C in a Thermomix® cooker-mixer. The solution density, in Brix, may be measured using an ATAGO® pocket refractometer. Sugar is then added, incrementally,

under constant mixing to produce a slurry containing sugar particles. The sugar may be pre-classified (*e.g.*, by sieving) to obtain a particular fraction or size distribution. Food-grade amorphous silica is then added incrementally, under constant mixing, to produce a slurry of sugar and silica particles in a substantially saturated sugar solution.

EXAMPLE 2

Under constant mixing, sugar is added to water (or an unsaturated sugar solution) in the Thermomix® cooker-mixer, to produce a concentrated sugar solution or sugar slurry that may be substantially saturated with respect to sugar (typically containing 90% to 95% of the amount sugar required to achieve saturation at that particular temperature). Alternatively, a substantially saturated solution is produced as follows: sugar is added in a 15% to 30% excess with respect to the requisite amount to achieve saturation at the target temperature. After 1 hour of mixing, a solid/liquid separation is performed (typically in a heated filtration unit) to separate off the excess sugar solids, leaving a clear, substantially saturated solution. Food-grade amorphous silica is added incrementally, under constant mixing. Sugar is then added incrementally, under constant mixing, to produce a slurry containing sugar particles and amorphous silica. This sugar may be pre-classified (*e.g.*, by sieving) to obtain a particular fraction or size distribution for introducing to the syrup. Typically, the temperature of the crystallizer contents is maintained at 60°C.

EXAMPLE 3

Under constant mixing, sugar is added to water in the Thermomix® cooker-mixer, to produce a solution substantially saturated with respect to sugar. Food-grade amorphous silica may be incrementally added to the water or sugar solution, under constant mixing. The addition of the silica may be prior to, concurrently with, or at least partially concurrently with the addition of the sugar. To the sugar solution containing the silica, sugar is added incrementally, under constant mixing, to produce a slurry containing sugar particles and silica. This sugar may be pre-classified (*e.g.*, by sieving) to obtain a particular fraction or size distribution.

EXAMPLE 4: Cooling Crystallization to Produce Coated Sugar Kernel Particles

The crystallizer is filled with a slurry containing sugar and food-grade amorphous silica in a concentrated syrup of sugar, *e.g.*, as prepared according to any of Examples 1-3, the slurry being maintained at a temperature within the range of 60-80°C under constant mixing using an IKA high-shear mixer. The crystallizer is then cooled, typically to 25-45°C, by means of the heat transfer fluid disposed within the jacket of the crystallizer. During the cooling, which usually takes about 2 hours, the saturation concentration of the sugar decreases, and the supersaturation yields a coating of sugar and silica on top of the pure sugar kernels.

EXAMPLE 5: Evaporative Cooling Crystallization to Produce Coated Sugar Kernel Particles

The crystallizer is filled with a slurry containing sugar and amorphous silica in a concentrated syrup of sugar, *e.g.*, as prepared according to any of Examples 1-3, the slurry being maintained at a temperature within the range of 60-80°C under constant mixing using the IKA High shear mixer for about 20 minutes. A vacuum is then applied so as to cool the crystallizer to 25-45°C, and to maintain the crystallizer at this temperature. During the cooling, which usually takes about 2 hours, the saturation concentration of the sugar decreases, and the supersaturation yields a coating of sugar and silica on top of the pure sugar kernels. It will be appreciated that for higher initial temperatures of the slurry, and/or for lower cooling temperatures within the crystallizer, the weight ratio of coating to kernel is increased.

EXAMPLE 6: Evaporative Crystallization to Produce Coated Sugar Kernel Particles

The crystallizer is filled with a slurry containing sugar and amorphous silica in a concentrated syrup of sugar, *e.g.*, as prepared according to any of Examples 1-3, the slurry being maintained at a temperature within the range of 60-80°C under constant mixing using IKA High shear mixer for about 20 minutes. A vacuum is then applied so as to evaporate water from the system while maintaining the temperature within the range of 60-80°C. The supersaturation produced yields a coating of sugar and silica on top of the pure sugar kernels.

EXAMPLE 7: Solid/Liquid Separation

Subsequent to the crystallization step (according to any of Examples 4-6), the slurry is immediately transferred to a filtering apparatus such as a belt filter or a centrifuge (*e.g.*, MRC model BK-30), typically operating at room temperature. The centrifuge separates the filtrate from the coated sugar to yield a wet sugar cake containing the coated sugar particles. It will be appreciated that the time of centrifugation may be varied to obtain a pre-determined or desirable level of moisture, with higher centrifugation times (and/or higher centrifugal force) being associated with lower ratios of coating weight to kernel weight or coating thickness to kernel size (radius or diameter).

EXAMPLE 8: Solid/Liquid Separation

Subsequent to the production of the slurry containing sugar and amorphous silica particles in a concentrated solution of sugar (*e.g.*, according to any of Examples 1-3), the slurry is immediately transferred into a filtering apparatus such as a belt filter or a centrifuge (*e.g.*, MRC model BK-30), typically operating at room temperature. The filtering apparatus separates the filtrate from the sugar particles to yield a wet sugar cake containing the sugar particles (surrounded by a layer of mother liquor). It will be appreciated that the time of filtration or centrifugation may be varied to obtain a pre-determined or desirable level of moisture, with

higher centrifugation times (and/or higher centrifugal force) being associated with lower ratios of coating weight to kernel weight or coating thickness to kernel size.

EXAMPLE 8A: Production of a Dry Coated Sugar Powder

The coated sugar produced (*e.g.*, by the method of Example 7 or Example 8) may be transferred into a fluidized bed drier (Retsch® TG 100). The drying program is typically performed as follows: 2 minutes at temperature 4, with the blower on level 3; 2 minutes at temperature 5, with the blower on level 4; and 2 minutes at temperature 6, with the blower on level 4.

EXAMPLE 9

A sweetener syrup containing one or more carbohydrate sweeteners and/or one or more polyol (typically sugar alcohol) sweeteners, is prepared prior to the addition of the silica. The temperature of the sweetener syrup is generally maintained within a range of 25°C to as much as 80°C, in some cases. For sucrose, the default temperature is 60°C. The concentration of sweetener, with respect to water, is typically within a range of 1wt%-65wt% (and may depend on the ratio between the silica and the sweetener) for most of the carbohydrate and polyol sweeteners. Some of the lower solubility sweeteners may require relatively high water concentrations and/or high temperatures in order to fully dissolve. The silica is then added incrementally under constant mixing. Once the silica addition has been completed, the mixing vessel continues to be stirred for at least 7 minutes using a high shear mixer, until the silica is fully dispersed within the sweetener syrup.

EXAMPLE 9A

Silica-sweetener concentrate syrup (*e.g.*, produced according to Example 9) may be transferred to the heated double-jacketed vessel of the vacuum dryer (*e.g.*, Stephan). The vessel is heated (typically to 60°C-70°C), maintained under vacuum, and mixed constantly, so as to evaporate the water, preferably at a slow, controlled rate, to achieve a low levels of global and local supersaturation within the stirred vessel. Eventually, a silica-sweetener concentrate powder is produced. Typically, the powder is crystalline or exhibits a distinct crystalline behavior that may be seen in an optical microscope and/or identified and quantified by means of XRD.

Optionally, the powder may be transferred to an oven (typically operating at 65°C) for further drying for several hours or overnight.

EXAMPLE 9B

The silica-sweetener concentrate, typically in powder form, may optionally undergo size reduction. The silica-sweetener powder may be milled to produce a fine powder having a D₅₀ that is typically within the range of 20 to 300 micrometers.

EXAMPLE 10

The silica-sweetener concentrate (e.g., as produced according to Example 8A or Example 9A), is diluted with at least one ordinary caloric sweetener (a carbohydrate sweetener and/or at least one polyol (typically a sugar alcohol) sweetener to yield the desired amount of silica in the sweetener formulation. For example: in order to prepare a “diluted” silica-sweetener formulation or “regular-strength silica-sweetener” formulation containing an average of 0.3% silica, from a silica-sweetener concentrate containing 50% silica; 0.6 grams of the silica-sweetener concentrate formulation is mixed with 99.4 grams of the ordinary carbohydrate sweeteners (e.g., sucrose) and/or polyol sweetener.

The silica-sweetener concentrate may have a D_{50} within a range of 20 to 300 micrometers, or may be subjected to size reduction to attain a D_{50} within this range.

EXAMPLE 11A: Utilization of the Sweetener Ingredient in the Production of an Edible Formulation

The “diluted” or “regular-strength” silica-sweetener formulation (e.g., as produced according to Example 10), which may be a mixture of silica-sweetener concentrate and ordinary sweetener, is added as an ingredient, along with other ingredients, and may be mixed and optionally processed further (e.g., baked) to produce an edible formulation (e.g., cake, muffins, biscuits).

EXAMPLE 11B

Another way to utilize the silica-sweetener concentrate formulation is by adding -- as separate ingredients -- the requisite amount of the silica-sweetener concentrate along with the ordinary sweetener (carbohydrate sweetener and/or polyol sweetener) during the preparation of the edible formulation (e.g., muffins). For example: to obtain, within the edible formulation, a sweetener having an *average* silica concentration of 0.3% from an ordinary sweetener and a concentrated silica-containing sweetener containing 50% silica, 0.6 grams of the silica-sweetener concentrate is added along with 99.4 grams of the ordinary sweetener. The silica-sweetener concentrate and the ordinary sweetener may thus be added as separate components, and not as a mixture.

EXAMPLE 12

A concentrated sugar syrup was prepared at 60°C by mixing 726g of Sugat[®] sugar (food-grade sucrose) with 210g of water, and subsequently filtering, according to Example 2, to produce a substantially saturated sugar solution containing about 605g of sugar. An additional quantity of the sugar was sieved to obtain the 500-600µm fraction, the other fractions being discarded. 600g of the sieved sugar (~500-600µm fraction) was added incrementally to the crystallizer over several minutes, under constant mixing. Subsequently, 6.0g of the silica (Syloid[®] 9005 PC) was incrementally added over 30 seconds, again under constant mixing. This

amount represents 0.5% by weight of pure silica with respect to the total amount of sugar in the process (*i.e.*, -- in the syrup + sieved sugar).

Cooling crystallization was then effected according to the procedure delineated in Example 4. The initial temperature of the slurry was about 70°C. The crystallizer was cooled to about 30°C, by means of the heat transfer fluid disposed within the jacket of the crystallizer, to produce the coated sugar kernel particles. The solid/liquid separation was performed according to Example 7, with a centrifugation time of 40 seconds. Drying of the silica-and-sugar coated sugar was performed by means of a fluidized bed drier, according to the procedure provided in Example 8A. The concentration of pure silica with respect to the concentration of sugar within the coated sugar particles was approximately 0.14%.

EXAMPLE 13

A concentrated sugar syrup was prepared at 60°C according to Example 12. An additional quantity of the sugar was sieved to obtain the 500-600µm fraction, the other fractions being discarded. 600g of the sieved sugar (500-600µm fraction) was added incrementally to the crystallizer over 1 minute, under constant mixing. Subsequently, 3.0g of the silica (Syloid® 9005) was incrementally added over 30 seconds, again under constant mixing. This amount represents 0.25% by weight of pure silica with respect to the total amount of sugar in the process (*i.e.*, -- in the syrup + sieved sugar).

Cooling crystallization was then effected according to the procedure delineated in Example 4. The initial temperature of the slurry was about 60°C. The crystallizer was cooled to about 30°C, by means of the heat transfer fluid disposed within the jacket of the crystallizer, to produce the coated sugar kernel particles. The solid/liquid separation was performed according to Example 7, with a centrifugation time of 40 seconds. Drying of the silica-and-sugar coated sugar was performed by means of a fluidized bed drier, according to the procedure provided in Example 8A. The concentration of pure silica with respect to the concentration of sugar within the coated sugar particles was approximately 0.06%.

EXAMPLE 14

A concentrated sugar syrup was prepared at 60°C according to Example 12. An additional quantity of the sugar was sieved to obtain the 500-600µm fraction, the other fractions being discarded. 600g of the sieved sugar (500-600µm fraction) was added incrementally to the crystallizer over 1 minute, under constant mixing. Subsequently, 6.0g of the silica (T-700) was incrementally added over 30 seconds, again under constant mixing. This amount represents 0.5% by weight of pure silica with respect to the total amount of sugar in the process (*i.e.*, -- in the syrup + sieved sugar).

Evaporative cooling crystallization was then effected according to the procedure delineated in Example 5. The initial temperature of the slurry was about 60°C. The crystallizer was cooled to about 30°C, by means of vacuum, to produce the coated sugar kernel particles. The solid/liquid separation was performed according to Example 7, with a centrifugation time of 40 seconds. Drying of the silica-and-sugar coated sugar was performed by means of a fluidized bed drier, according to the procedure provided in Example 8A.

The dried silica-and-sugar coated sugar product weighed 729g, representing an increase of 124g (729g - 605g) or 20.5% with respect to the weight of the sugar kernels, and 17% (124g/729g) with respect to the entirety of the coated sugar particles. The silica content of the dried silica-and-sugar coated sugar product was 1.2 grams, all of which was disposed in the coating. Thus, the average silica concentration within the coating was 1.2g/124g, or about 1.0%, and the average silica:sugar weight ratio within the coating was 1.2g/122.8g, or about 0.01. The average concentration of silica with respect to the concentration of sugar within the entirety of the coated sugar particles was 1.2g/729g, or about 0.16%, and the average silica:sugar weight ratio within the entirety of the coated sugar particles was 1.2g/727.8g, or about 0.0016.

EXAMPLE 15

A concentrated sugar syrup was prepared at 60°C according to Example 12. An additional quantity of the sugar was sieved to obtain the 500-600µm fraction, the other fractions being discarded. 600g of the sieved sugar (500-600µm fraction) was added incrementally to the crystallizer over 1 minute, under constant mixing. Subsequently, 2.0g of the silica (Syloid® 9005) was incrementally added over 30 seconds, again under constant mixing. This amount represents about 0.17% by weight of pure silica with respect to the total amount of sugar in the process (*i.e.*, -- in the syrup + sieved sugar).

Cooling crystallization was then effected according to the procedure delineated in Example 4. The initial temperature of the slurry was about 70°C. The crystallizer was cooled to about 30°C, by means of the heat transfer fluid disposed within the jacket of the crystallizer, to produce the coated sugar kernel particles. The solid/liquid separation was performed according to Example 7, with a centrifugation time of 40 seconds. Drying of the silica-and-sugar coated sugar was performed by means of a fluidized bed drier, according to the procedure provided in Example 8A.

The weight of the coating, which consisted of sugar and sweetener, was about 123 grams, or about 17% with respect to the original weight of the sugar kernel. The amount of pure silica within the coated layer was 0.36 grams, corresponding to about 0.29% (0.36/123) of the coating, which is the average concentration (by weight) on a silica to sweetener (sugar) basis, within the coating. The concentration of pure silica with respect to the concentration of sugar within the

coated sugar particles, *i.e.*, the average concentration, by weight, on a silica to sweetener (sugar) basis was 0.05%.

This is approximately equal to the average concentration (by weight) of silica in the coated particles, which was also about 0.05%.

The silica-and-sugar coated sugar was then diluted by adding Sugat[®] table sugar in a 1:1 ratio (Sugat[®]:coated sugar). This lowered the concentration of pure silica with respect to the concentration of sugar within the sugar formulation to 0.025%.

EXAMPLE 16

A concentrated sugar syrup was prepared at 60°C according to Example 12. An additional quantity of the sugar was sieved to obtain the 500-600µm fraction, the other fractions being discarded. 600g of the sieved sugar (500-600µm fraction) was added incrementally to the crystallizer over 1 minute, under constant mixing. Subsequently, 4.0g of the silica (Flo-gard[™] T-800) was incrementally added over 30 seconds, again under constant mixing. This amount represents 0.33% by weight of pure silica with respect to the total amount of sugar in the process (*i.e.*, -- in the syrup + sieved sugar).

Evaporative cooling crystallization was then effected according to the procedure delineated in Example 5. The initial temperature of the slurry was about 60°C. The crystallizer was cooled to about 30°C, by means of vacuum, to produce the coated sugar kernel particles. The solid/liquid separation was performed according to Example 7, with a centrifugation time of 40 seconds. Drying of the silica-and-sugar coated sugar was performed by means of a fluidized bed drier, according to the procedure provided in Example 8A. The concentration of pure silica with respect to the concentration of sugar within the coated sugar particles was approximately 0.1%.

EXAMPLE 17

A concentrated sugar syrup was prepared at 60°C according to Example 12. An additional quantity of the sugar was sieved to obtain the 500-600µm fraction, the other fractions being discarded. 600g of the sieved sugar (500-600µm fraction) was added incrementally to the crystallizer over 1 minute, under constant mixing. Subsequently, 5.0g of the silica (Flo-gard[™] 915) was incrementally added over 30 seconds, again under constant mixing. This amount represents about 0.41% by weight of pure silica with respect to the total amount of sugar in the process (*i.e.*, -- in the syrup + sieved sugar).

Cooling crystallization was then effected according to the procedure delineated in Example 4. The initial temperature of the slurry was about 60°C. The crystallizer was cooled to about 30°C, by means of the heat transfer fluid disposed within the jacket of the crystallizer, to produce silica-and-sugar coated sugar kernel particles. The solid/liquid separation was

performed according to Example 7, with a centrifugation time of 40 seconds. Drying of the silica-and-sugar coated sugar was performed by means of a fluidized bed drier, according to the procedure provided in Example 8A. The weight of the coating, which consisted of sugar and sweetener, was about 138 grams, or about 23% with respect to the original weight of the sugar kernel. The amount of pure silica within the coated layer was approximately 0.72 grams, corresponding to an average concentration of about 0.52% of the coating, by weight. The average concentration of pure silica with respect to the average concentration of sugar within the coated sugar particles (*i.e.*, average concentration, on a silica to sugar basis) was approximately 0.1%.

The silica-and-sugar coated sugar was then diluted by a factor of 2 by adding Sugat[®] table sugar in a 1:1 ratio (Sugat[®]:coated sugar). This lowered the average concentration of pure silica with respect to the average concentration of sugar within the sugar formulation to about 0.05%.

EXAMPLE 18

A concentrated sugar syrup was prepared at 60°C according to Example 12. An additional quantity of the sugar was sieved to obtain the 500-600µm fraction, the other fractions being discarded. 600g of the sieved sugar (500-600µm fraction) was added incrementally to the crystallizer over 1 minute, under constant mixing. Subsequently, 20g of the silica (Flo-gard[™] 915) was incrementally added over 30 seconds, again under constant mixing. This amount represents 1.66% by weight of pure silica with respect to the total amount of sugar in the process (*i.e.*, -- in the syrup + sieved sugar).

Cooling crystallization was then effected according to the procedure delineated in Example 4. The initial temperature of the slurry was about 70°C. The crystallizer was cooled to about 30°C, by means of the heat transfer fluid disposed within the jacket of the crystallizer, to produce silica-and-sugar coated sugar kernel particles. The solid/liquid separation was performed according to Example 7, with a centrifugation time of 40 seconds. Drying of the silica-and-sugar coated sugar was performed by means of a fluidized bed drier, according to the procedure provided in Example 8A. The weight of the coating was about 126 grams, or about 21% with respect to the original weight of the sugar kernel. The amount of pure silica within the coated layer was approximately 4.8 grams, corresponding to about 4.0% of the coating (silica:sugar), by weight. The average concentration of pure silica with respect to the average concentration of sugar within the coated sugar particles (*i.e.*, average concentration on a silica to sugar basis) was approximately 0.66%.

The silica-and-sugar coated sugar was then diluted by a factor of 4 by adding Sugat[®] table sugar in a 3:1 ratio (Sugat[®]:coated sugar). This lowered the average concentration of pure

silica with respect to the average concentration of sugar within the sugar formulation to about 0.17%.

EXAMPLE 19

A concentrated sugar syrup was prepared at 60°C according to Example 12. An additional quantity of the sugar was sieved to obtain the 500-600µm fraction, the other fractions being discarded. 600g of the sieved sugar (500-600µm fraction) was added incrementally to the crystallizer over 1 minute, under constant mixing. Subsequently, 1.5g of the silica (Flo-gard™ 233) was incrementally added over 30 seconds, again under constant mixing. This amount represents 0.13% by weight of pure silica with respect to the total amount of sugar in the process (*i.e.*, -- in the syrup + sieved sugar).

Cooling crystallization was then effected according to the procedure delineated in Example 4. The initial temperature of the slurry was about 70°C. The crystallizer was cooled to about 30°C, by means of the heat transfer fluid disposed within the jacket of the crystallizer, to produce the coated sugar kernel particles. The solid/liquid separation was performed according to Example 7, with a centrifugation time of 40 seconds. Drying of the silica-and-sugar coated sugar was performed by means of a fluidized bed drier, according to the procedure provided in Example 8A. The average concentration of pure silica with respect to the average concentration of sugar within the coated sugar particles was approximately 0.04%.

EXAMPLE 20

A concentrated sugar syrup was prepared at 60°C according to Example 12. An additional quantity of the sugar was sieved to obtain the 500-600µm fraction, the other fractions being discarded. 600g of the sieved sugar (500-600µm fraction) was added incrementally to the crystallizer over 1 minute, under constant mixing. Subsequently, 12g of the silica (Flo-gard™ T-700) was incrementally added over 30 seconds, again under constant mixing. This amount represents 1% by weight of pure silica with respect to the total amount of sugar in the process (*i.e.*, -- in the syrup + sieved sugar).

Evaporative cooling crystallization was then effected according to the procedure delineated in Example 5. The initial temperature of the slurry was about 70°C. The crystallizer was cooled to about 30°C, by means of vacuum, to produce the coated sugar kernel particles. The solid/liquid separation was performed according to Example 7, with a centrifugation time of 40 seconds. Drying of the silica-and-sugar coated sugar was performed by means of a fluidized bed drier, according to the procedure provided in Example 8A. The weight of the coating was about 198 grams, or about 33% with respect to the original weight of the sugar kernel. The amount of pure silica within the coated layer was 3.99 grams, corresponding to an average concentration of about 2.0% of the coating. The concentration of pure silica with respect to the

concentration of sugar within the coated sugar particles (*i.e.*, average concentration on a silica to sugar basis) was 0.5%.

The silica-and-sugar coated sugar was then diluted by adding Sugat[®] table sugar in a 5.2:1 ratio (Sugat[®]:coated sugar). This lowered the average concentration of pure silica with respect to the average concentration of sugar within the sugar formulation to 0.08%.

EXAMPLE 21

A concentrated sugar syrup was prepared at 60°C according to Example 12. An additional quantity of the sugar was sieved to obtain the 500-600µm fraction, the other fractions being discarded. 600g of the sieved sugar (500-600µm fraction) was added incrementally to the crystallizer over 1 minute, under constant mixing. Subsequently, 60g of the silica (Flo-gard[™] T-700) was incrementally added over 30 seconds, again under constant mixing. This amount represents 5% by weight of pure silica with respect to the total amount of sugar in the process (*i.e.*, -- in the syrup + sieved sugar).

Evaporative cooling crystallization was then effected according to the procedure delineated in Example 5. The initial temperature of the slurry was about 60°C. The crystallizer was cooled to about 30°C, by means of vacuum, to produce the coated sugar kernel particles. The solid/liquid separation was performed according to Example 7, with a centrifugation time of 40 seconds. Drying of the silica-and-sugar coated sugar was performed by means of a fluidized bed drier, according to the procedure provided in Example 8A. The weight of the coating was about 108 grams, or about 18% with respect to the original weight of the sugar kernel. The amount of pure silica within the coated layer was approximately 11.9 grams, corresponding to about 11% of the coating, by average concentration. The average concentration of pure silica with respect to the average concentration of sugar within the coated sugar particles (*i.e.*, average concentration on a silica to sugar basis) was approximately 1.71%, which corresponds to an average silica concentration of about 1.68% within the coated particles.

The silica-and-sugar coated sugar was then diluted by a factor of 8.5 by adding Sugat[®] table sugar in a 7.5:1 ratio (Sugat[®]:coated sugar). This lowered the average concentration of pure silica with respect to the average concentration of sugar within the sugar formulation to about 0.2%.

EXAMPLE 22

A concentrated sugar syrup was prepared at 60°C according to Example 12. An additional quantity of the sugar was sieved to obtain the 500-600µm fraction, the other fractions being discarded. 600g of the sieved sugar (500-600µm fraction) was added incrementally to the crystallizer over 1 minute, under constant mixing. Subsequently, 4g of the silica (Flo-gard[™] T-800) was incrementally added over 30 seconds, again under constant mixing. This amount

represents about 0.33% by weight of pure silica with respect to the total amount of sugar in the process (*i.e.*, -- in the syrup + sieved sugar).

The solid/liquid separation was performed according to Example 8, with a centrifugation time of 40 seconds. Drying of the silica-and-sugar coated sugar was performed by means of a fluidized bed drier, according to the procedure provided in Example 8A. The average concentration of pure silica with respect to the average concentration of sugar within the coated sugar particles was approximately 0.08%.

EXAMPLE 23

A concentrated sugar syrup was prepared at 60°C according to Example 12. An additional quantity of the sugar was sieved to obtain the 500-600µm fraction, the other fractions being discarded. 600g of the sieved sugar (500-600µm fraction) was added incrementally to the crystallizer over 1 minute, under constant mixing. Subsequently, 4g of the silica (Flo-gard™ T-800) was incrementally added over 30 seconds, again under constant mixing. This amount represents about 0.33% by weight of pure silica with respect to the total amount of sugar in the process (*i.e.*, -- in the syrup + sieved sugar).

The solid/liquid separation was performed according to Example 8, with a centrifugation time of 25 seconds. Drying of the silica-and-sugar coated sugar was performed by means of a fluidized bed drier, according to the procedure provided in Example 8A. The average concentration of pure silica with respect to the average concentration of sugar within the coated sugar particles was approximately 0.11%.

EXAMPLE 24

Example 19 was repeated, using sorbitol instead of sugar. The average concentration of pure silica with respect to the average concentration of sugar within the coated sugar particles was approximately 0.10%.

EXAMPLE 25

Example 16 was repeated, using sorbitol instead of sugar. The average concentration of pure silica with respect to the average concentration of sugar within the coated sugar particles was approximately 0.12%.

EXAMPLE 26: Etching of the Silica-and-Sweetener Coated Sweetener Particles

In order to characterize the outer layer of the coated sweetener particles, an etching process was performed on the coated sweetener particles. It will be appreciated by those of skill in the art that the etching process may be designed to remove a portion of the coating without dissolving any (or very little) of the sweetener kernel. Alternatively, the etching process may be designed to remove substantially all of the coating, while dissolving only a portion or small portion of the sweetener kernel.

Each fraction from the etching process may be separately processed and analyzed to determine the respective concentration of silica.

In the case of sugar (typically sucrose), by way of example, an ethanol and water mixture (4:1 w:w) is used as the etching solvent. Typically, the sugar sample is sieved to provide a 500-595 μ m fraction, using ASTM sieves Nos. 30, 35. 10g of this fraction of the sugar is mixed with 50ml of the EtOH:water mixture for 12 minutes at 400 rpm using an overhead stirrer. The resultant slurry is filtered, and the cake (containing the “etched” sugar particles) is oven-dried overnight at 65°C. An ash test is performed on the etched sugar in order to evaluate the silica concentration. This concentration may be compared to the silica concentration in the original sample of coated sugar (which may be quantified by the same ash test), and/or with the silica concentration in the dried filtrate (which may be quantified by the same ash test). The silica concentration in the dried filtrate represents the concentration of silica in the etched fraction.

It will be appreciated by those of skill in the art that various other analytical techniques may be used to characterize the outer layer or coating of the silica-and-sweetener coated sweetener particles, and to compare the characteristics with those of the material underlying the coating.

EXAMPLE 27

A dispersion (slurry) containing 50% amorphous silica and 50% sucrose was prepared according to Example 9: 100 grams of silica were added gradually to a sucrose syrup containing 100 grams sucrose and 500 grams water. The syrup containing the silica was then transferred to the heated double-jacketed vessel of the vacuum dryer, which was heated and maintained under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder.

EXAMPLE 28

A dispersion (slurry) containing 70% amorphous silica and 30% sucrose was prepared according to Example 9: 100 grams of silica were added gradually to sucrose syrup containing 42.8 grams sucrose and 500 grams water. The syrup containing the silica was then transferred to the heated double-jacketed vessel of the vacuum dryer, which was heated and maintained under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder.

EXAMPLE 29

A dispersion (slurry) containing 10% amorphous silica and 90% sucrose was prepared according to Example 9: 100 grams of silica were added gradually to sucrose syrup containing 900 grams sucrose and 500 grams water. The syrup containing the silica was then transferred to the heated double-jacketed vessel of the vacuum dryer, which was heated and maintained under

vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder.

EXAMPLE 30

A dispersion (slurry) containing 30% amorphous silica and 70% sucrose was prepared according to Example 9: 100 grams of silica were added gradually to sucrose syrup containing 233.3 grams sucrose and 500 grams water. The syrup containing the silica was then transferred to the heated double-jacketed vessel of the vacuum dryer, which was heated and maintained under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder.

EXAMPLE 31

A dispersion containing 1% amorphous silica and 99% sucrose was prepared according to Example 9: a concentrated sweetener syrup containing 650 grams sucrose was prepared prior to the addition of the silica. 6.5 grams of silica were then dispersed in the concentrated sweetener syrup. The syrup was transferred to the heated double-jacketed vessel of the vacuum dryer, which was heated and maintained under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder.

EXAMPLE 32

A dispersion containing 1.5% amorphous silica and 98.5% sucrose was prepared according to Example 9: a concentrated sweetener syrup containing 650 grams sucrose was prepared prior to the addition of the silica. 9.75 grams of silica were then dispersed in the concentrated sweetener syrup. The syrup was transferred to the heated double-jacketed vessel of the vacuum dryer, which was heated and maintained under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder.

EXAMPLE 33

A dispersion (slurry) containing 40% amorphous silica and 60% sucrose was prepared according to Example 9: 100 grams of silica were added gradually to sucrose syrup containing 150 grams sucrose and 500 grams water. The syrup containing the silica was then transferred to the heated double-jacketed vessel of the vacuum dryer, which was heated and maintained under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder.

EXAMPLE 34

A dispersion (slurry) containing 20% amorphous silica and 80% sucrose was prepared according to Example 9: 100 grams of silica were added gradually to sucrose syrup containing 400 grams sucrose and 500 grams water. The syrup containing the silica was then transferred to the heated double-jacketed vessel of the vacuum dryer, which was heated and maintained under

vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder.

EXAMPLE 35

A dispersion (slurry) containing 60% amorphous silica and 40% sucrose was prepared according to Example 9: 100 grams of silica were added gradually to sucrose syrup containing 66.6 grams sucrose and 500 grams water. The syrup containing the silica was then transferred to the heated double-jacketed vessel of the vacuum dryer, which was heated and maintained under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder.

EXAMPLES 36-44

The formulations of Examples 27 to 35 were prepared, but using fructose instead of sucrose.

EXAMPLE 45

A silica-sweetener concentrate was produced by processing the formulation of Example 27 according to Example 9, and subsequently heating under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder. The powder was subjected to size reduction according to Example 9B. The milled silica-sweetener concentrate powder was then mixed with ordinary sugar according to Example 10: 0.16 grams of the powder were mixed with 79.84 grams of sucrose to yield 80 grams of the final sweetener formulation, which contained an average silica concentration of 0.1%.

EXAMPLE 46

A silica-sweetener concentrate was produced by processing the formulation of Example 33 according to Example 9, and subsequently heating under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder. The powder was subjected to size reduction according to Example 9B. The milled silica-sweetener concentrate powder was then mixed with ordinary sugar according to Example 10: 0.2 grams of the powder were mixed with 79.8 grams of sucrose to yield 80 grams of the final sweetener formulation, which contained an average silica concentration of 0.1%.

EXAMPLE 47

A silica-sweetener concentrate was produced by processing the formulation of Example 29 according to Example 9, and subsequently heating under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder. The powder was subjected to size reduction according to Example 9B. The milled silica-sweetener concentrate powder was then mixed with ordinary sugar according to Example 10: 0.8 grams of the powder were mixed

with 79.2 grams of sucrose to yield 80 grams of the final sweetener formulation, which contained an average silica concentration of 0.1%.

EXAMPLE 48

A silica-sweetener concentrate was produced by processing the formulation of Example 29 according to Example 9, and subsequently evaporating under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder. The powder was subjected to size reduction according to Example 9B. The silica-sweetener concentrate powder was then mixed with ordinary sugar according to Example 10: 5 grams of the powder was mixed with 95 grams of sucrose to yield 100 grams of the final sweetener formulation, which contained an average silica concentration of 0.5%.

EXAMPLE 49

A silica-sweetener concentrate was produced by processing the formulation of Example 27 according to Example 9, and subsequently heating under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder. The powder was subjected to size reduction according to Example 9B. The milled silica-sweetener concentrate powder was then mixed with ordinary sugar according to Example 10: 1.6 grams of the powder were mixed with 78.4 grams of sucrose to yield 80 grams of the final sweetener formulation, which contained an average silica concentration of 1%.

EXAMPLE 50

A silica-sweetener concentrate was produced by processing the formulation of Example 27 according to Example 9, and subsequently heating under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder. The powder was subjected to size reduction according to Example 9B. The milled silica-sweetener concentrate powder was then mixed with ordinary sugar according to Example 10: 0.08 grams of the powder were mixed with 79.92 grams of sucrose to yield 80 grams of the final sweetener formulation, which contained an average silica concentration of 0.05%.

EXAMPLE 51

A silica-sweetener concentrate was produced by processing the formulation of Example 29 according to Example 9, and subsequently heating under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder. The powder was subjected to size reduction according to Example 9B. The milled silica-sweetener concentrate powder was then mixed with ordinary sugar according to Example 10: 1.6 grams of the powder were mixed with 78.4 grams of sucrose to yield 80 grams of the final sweetener formulation, which contained an average silica concentration of 0.2%.

EXAMPLE 52

A silica-sweetener concentrate was produced by processing the formulation of Example 27 according to Example 9, and subsequently heating under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder. The powder was subjected to size reduction according to Example 9B. The milled silica-sweetener concentrate powder was then mixed with ordinary sugar according to Example 10: 0.32 grams of the powder were mixed with 79.68 grams of sucrose to yield 80 grams of the final sweetener formulation, which contained an average silica concentration of 0.2%.

EXAMPLE 53

A silica-sweetener concentrate was produced by processing the formulation of Example 30 according to Example 9, and subsequently heating under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder. The powder was subjected to size reduction according to Example 9B. The milled silica-sweetener concentrate powder was then mixed with ordinary sugar according to Example 10: 0.5 grams of the powder were mixed with 99.5 grams of sucrose to yield 100 grams of the final sweetener formulation, which contained an average silica concentration of 0.15%.

EXAMPLE 54

A silica-sweetener concentrate was produced by processing the formulation of Example 29 according to Example 9, and subsequently heating under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder. The powder was subjected to size reduction according to Example 9B. The milled silica-sweetener concentrate powder was then mixed with ordinary sugar according to Example 3: 1.6 grams of the powder were mixed with 78.4 grams of sucrose to yield 80 grams of the final sweetener formulation, which contained an average silica concentration of 0.2%.

EXAMPLE 55

A silica-sweetener concentrate was produced by processing the formulation of Example 29 according to Example 9, and subsequently heating under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder. The powder was subjected to size reduction according to Example 9B. The milled silica-sweetener concentrate powder was then mixed with ordinary sugar according to Example 10: 0.5 grams of the powder were mixed with 99.5 grams of sucrose to yield 100 grams of the final sweetener formulation, which contained an average silica concentration of 0.05%.

EXAMPLE 56

A silica-sweetener concentrate was produced by processing the formulation of Example 32 according to Example 9, and subsequently heating under vacuum according to Example 9A,

to produce a silica-sweetener concentrate as a fine dry powder. The powder was subjected to size reduction according to Example 9B. The milled silica-sweetener concentrate powder was then mixed with ordinary sugar according to Example 10: 16 grams of the powder were mixed with 84 grams of sucrose to yield 100 grams of the final sweetener formulation, which contained an average silica concentration of 0.24%.

EXAMPLE 57

A silica-sweetener concentrate was produced by processing the formulation of Example 33 according to Example 9, and subsequently heating under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder. The powder was subjected to size reduction according to Example 9B. The milled silica-sweetener concentrate powder was then mixed with ordinary sugar according to Example 10: 2.5 grams of the powder were mixed with 97.5 grams of sucrose to yield 100 grams of the final sweetener formulation, which contained an average silica concentration of 1%.

EXAMPLE 58

A silica-sweetener concentrate was produced by processing the formulation of Example 30 according to Example 9, and subsequently heating under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder. The powder was subjected to size reduction according to Example 9B. The milled silica-sweetener concentrate powder was then mixed with ordinary sugar according to Example 10: 0.166 grams of the powder were mixed with 99.833 grams of sucrose to yield 100 grams of the final sweetener formulation, which contained an average silica concentration of 0.05%.

EXAMPLE 59

A silica-sweetener concentrate was produced by processing the formulation of Example 30 according to Example 9, and subsequently heating under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder. The powder was subjected to size reduction according to Example 9B. The milled silica-sweetener concentrate powder was then mixed with ordinary sugar according to Example 10: 0.5 grams of the powder were mixed with 99.5 grams of sucrose to yield 100 grams of the final sweetener formulation, which contained an average silica concentration of 0.15%.

EXAMPLE 60

A silica-sweetener concentrate was produced by processing the formulation of Example 34 according to Example 9, and subsequently heating under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder. The powder was subjected to

size reduction according to Example 9B. The milled silica-sweetener concentrate powder was then mixed with ordinary sugar according to Example 10: 0.5 grams of the powder were mixed with 99.5 grams of sucrose to yield 100 grams of the final sweetener formulation, which contained an average silica concentration of 0.1%.

EXAMPLE 61

A silica-sweetener concentrate was produced by processing the formulation of Example 35 according to Example 9, and subsequently heating under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder. The powder was subjected to size reduction according to Example 9B. The milled silica-sweetener concentrate powder was then mixed with ordinary sugar according to Example 10: 0.6 grams of the powder were mixed with 79.4 grams of sucrose to yield 80 grams of the final sweetener formulation, which contained an average silica concentration of 0.45%.

EXAMPLE 62

A dispersion (slurry) containing 30% silica and 70% allulose was prepared according to Example 9: 51.5 grams of amorphous silica were added gradually to an allulose syrup containing 120 grams allulose and 480 grams water. The syrup containing the silica was then transferred to the heated double-jacketed vessel of the vacuum dryer, which was heated and maintained under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder.

EXAMPLE 63

A silica-sweetener concentrate was produced by processing the formulation of Example 28 according to Example 9, and subsequently heating under vacuum according to Example 9A, to produce a silica-sweetener concentrate as a fine dry powder. The powder was subjected to size reduction according to Example 9B. The silica-sweetener concentrate powder was then mixed with allulose according to Example 10: 0.32 grams of the powder was mixed with 79.68 grams of allulose to yield 80 grams of the final sweetener formulation, which contained an average silica concentration of 0.28%.

EXAMPLES 64-72

The formulations of Examples 27 to 35 were prepared, but using maltitol instead of sucrose, and using 700 grams water.

EXAMPLES 73-81

The formulations of Examples 27 to 35 were prepared, but using sorbitol instead of sucrose, and using 700 grams water.

EXAMPLE 82: Preparation of Muffin Samples

Three types of muffin samples may be prepared. Type I is a “full sugar” control muffin, which may be similar in composition to typical, commercially available muffins. Type II is an inventive, reduced-sugar muffin containing the inventive silica-sweetener or silica-sweetener concentrate. Type III is a reduced sugar control muffin, having the identical composition as the Type II inventive, reduced-sugar muffin, but being devoid of the silica in the sweetener particles.

The batter for each type of muffin contains sugar, 14.2% sunflower oil, 21.8% wheat flour (containing approximately 40% starch), 24.5% eggs, baking powder (1.1%), flavors or flavorants (0.1%), salt (0.1%), and about 16.4% water. The batter of the Type I muffin contains 21.8 wt.% sugar.

A fructooligosaccharide is used as a filler to make up for the reduced amount of sugar in the Type II and Type III samples. Typically, Gofos™ (typically containing 2% sugar) is utilized.

The Type II muffin utilizes a sweetener formulation from various exemplary formulations (many of which are described or exemplified hereinabove). Aside from the formulative differences, the preparation and baking process is identical for the inventive muffin and the control muffins.

EXAMPLE 82A

Typically, the Type II inventive, reduced-sugar muffin contains 39.1% less sugar with respect to the Type I “full sugar” control muffin. For this exemplary case, the Type II and Type III muffins are formulated such that the batter contains about $(100\% - 39.1\%) \cdot 21.8\% = 13.3$ wt.% sugar. The fructooligosaccharide (Gofos™) content of the muffin batter is about 8.5wt% $(21.8\% - 13.38\%)$.

EXAMPLE 82B

In many cases, the Type II inventive, reduced-sugar muffin may contain reduced sugar in an amount other than the typical reduction of 39.1%. By way of (non-exhaustive) example, the Type II muffin may contain 50% less sugar, 35% less sugar, 20% less sugar, or 10% less sugar. For an exemplary case of 20% less sugar, the Type II muffin is formulated such that the batter contains about $(100\% - 20\%) \cdot 21.8\% = 17.44$ wt.% sugar, and 4.36 wt.% Gofos™ $(21.8\% - 17.44\%)$. In any event, strictly for comparative purposes, the Type II muffin contains at least 10% less sugar with respect to the Type I “full sugar” control muffin.

EXAMPLE 83: Preparation of Butter Cookie Samples

Three types of butter cookie samples may be prepared. Type I is a “full sugar” control butter cookie, which may be similar in composition to typical, commercially available butter cookies. Type II is an inventive, reduced-sugar butter cookie containing the inventive silica-

sweetener or silica-sweetener concentrate. Type III is a reduced sugar control butter cookie, having the identical composition as the Type II inventive, reduced-sugar butter cookie, but being devoid of the silica in the sweetener particles.

The batter for each type of butter cookie contains sugar, 14.6% palm oil, 49.42% wheat flour (containing approximately 40% starch), corn starch (4.2%), water (5.7%), egg (3.6%), soy lecithin (0.19%), baking powder (0.3%), salt (0.2%), 1.2% invert sugar (containing 5% water), 1.5% heavy cream (containing 37% fat and 3.5% lactose), flavor or flavorants (0.1%), with water being the remainder. The sugar content of the Type I butter cookie is about 19.0%.

Inulin is used as a filler to make up for the reduced amount of sugar in the Type II and Type III samples. Typically, Orafit High Soluble Inulin (which contains 10% sugar) is utilized.

The Type II butter cookie utilizes a sweetener formulation from various exemplary formulations (many of which are described or exemplified hereinabove). Aside from the formulative differences, the preparation and baking process is identical for the inventive butter cookie and the control butter cookies.

EXAMPLE 83A

Typically, the Type II inventive, reduced-sugar butter cookie contains about 40% less sugar with respect to the Type I “full sugar” control butter cookie. For this exemplary case, the Type II and Type III butter cookies are formulated such that the batter contains about $(100\% - 40.45\%) \cdot 19.0\% = 11.3 \text{ wt.\%}$ sugar. The inulin content of the batter is about 7.7wt.% $(19.0\% - 11.3\%)$. Substantially as in the case of the muffin samples provided hereinabove, in many cases, the Type II inventive, reduced-sugar butter cookie may contain reduced sugar in an amount other than the typical reduction of about 40%. By way of (non-exhaustive) example, the Type II butter cookie may contain 50% less sugar, 40% less sugar, 35% less sugar, 20% less sugar, or 10% less sugar. Strictly for comparative purposes, the Type II butter cookie contains at least 10% less sugar with respect to the Type I “full sugar” control butter cookie.

EXAMPLE 84: Preparation of Hazelnut Spread Samples

Three types of hazelnut spread samples may be prepared. Type I is a “full sugar” control hazelnut spread, which may be similar in composition to typical, commercially available hazelnut spreads. Type II is an inventive, reduced-sugar hazelnut spread containing the inventive silica-sweetener or silica-sweetener concentrate. Type III is a reduced sugar control hazelnut spread, having the identical composition as the Type II inventive, reduced-sugar hazelnut spread, but being devoid of the silica in the sweetener particles.

Each type of hazelnut spread contains sugar, hazelnut paste (13%), palm oil (23.7%), cocoa powder (7.4%) having 12% fat, skim milk powder (6.6%), rapeseed lecithin (0.2%) and flavors or flavorants (0.1%). The sugar content of the Type I hazelnut spread is 49%.

A fructooligosaccharide is used as a filler to make up for the reduced amount of sugar in the Type II and Type III samples. Typically, Inulin is utilized. The Type II hazelnut spread utilizes a sweetener formulation from various exemplary formulations (many of which are described or exemplified hereinabove). Aside from the formulative differences, the preparation process is identical for the inventive hazelnut spread and the control hazelnut spreads.

EXAMPLE 84A

Typically, the Type II inventive, reduced-sugar hazelnut spread contains about 41% less sugar with respect to the Type I “full sugar” control hazelnut spread. For this exemplary case, the Type II and Type III hazelnut spreads are formulated to contain about $(100\%-30\%)\cdot 49\% = 34.3$ wt.% sugar. The inulin content of the hazelnut spread is about 14.7 wt.% $(49\% - 34.3\%)$.

Substantially as in the case of the hazelnut spread samples provided hereinabove, in many cases, the Type II inventive, reduced-sugar hazelnut spread may contain reduced sugar in an amount other than the typical reduction of 30%. By way of (non-exhaustive) example, the Type II hazelnut spread may contain 50% less sugar, 35% less sugar, 20% less sugar, or 10% less sugar. Strictly for comparative purposes, the Type II hazelnut spread contains at least 10% less sugar with respect to the Type I “full sugar” control hazelnut spread.

EXAMPLE 85: Sensory Evaluation

The exemplary sweetener or edible formulations (e.g., muffins, butter cookies and hazelnut spreads) may be evaluated by trained sensory panelists using a paired-comparison test. The paired-comparison test is a two-product blind test, and the panelists’ task is to choose/indicate the sweeter one of the two products or samples (Sensory Evaluation Practices, 4th Ed., Stone, Bleibaum, Thomas, eds.). The results are analyzed using binomial distribution tables, which allows the sensory scientist to determine whether perceived differences between the samples are statistically significant. A Comparative Sweetness Index may be calculated from the paired-comparison test results, compiled from all the panelists. For example, if, among 17 panelists, 10 chose the inventive product as being sweeter, while the other 7 panelists chose the comparative or control product, the Comparative Sweetness Index (CSI) would be calculated as:

$$\text{CSI} = (10/17) \cdot 100 = 58.8 = 59 \text{ (rounded)}$$

EXAMPLE 85A

Another sensory method used to evaluate samples is difference magnitude estimation (DME). Here, each panelist tastes the two samples, choose the sweetest, and also chooses the difference in sweetness, from the following list:

- ☐ No difference at all
- ☐ Extremely small difference
- ☐ Small difference
- ☐ Moderate difference
- ☐ Large difference
- ☐ Extremely large difference

Each choice is given a numerical value (0-5), and the average of the panel is calculated (when the first (inventive, silica-containing) sample is indicated as sweeter, the values are taken as positive, and vice versa). Generally, a difference of up to ± 1.0 (i.e., within an absolute value of 1), and in some cases, up to ± 0.8 or up to ± 0.5 , is considered to be insignificant (i.e., the sweetness of the samples is substantially the same). An insignificant difference is considered to be a good result for the inventive formulation vs. the control formulation.

EXAMPLES 86-87

Various formulations exemplified hereinabove were used to prepare muffin samples, according to Examples 82 and 82A. Pair-comparison test results of the pair-comparison tests, performed and evaluated according to Examples 85 and 85A, are listed below in Table 1.

EXAMPLES 88-91

Various formulations exemplified hereinabove were used to prepare butter cookie samples, according to Examples 83 and 83A. Pair-comparison test results of the pair-comparison tests, performed and evaluated according to Examples 85 and 85A, are listed below in Table 1.

EXAMPLES 92-93

Various formulations exemplified hereinabove were used to prepare hazelnut spread, according to Examples 84 and 84A. Pair-comparison test results of the pair-comparison tests, performed and evaluated according to Examples 85 and 85A, are listed below in Table 1.

TABLE 1

Example No.	Example No. of diluted sweetener	Example No. of silica-sweetener concentrate	% Silica in Concentrate (Nominal)	% silica within the diluted sweetener	DME	Comparative Sweetness Index (CSI)
88(BC)	50	27	50	0.05	0.69	69%
89(BC)	45	27	50	0.1	0.21	60%
90(BC)	52	27	50	0.2	-1.43	7%
91(BC)	60	34	20	0.1	-0.47	47%
92(HZ)	34	29	10	0.1	-0.33	42%
93(HZ)	45	27	50	0.1	-0.33	50%
86(M)	45	27	50	0.1	0.07	53%
87(M)	34	29	10	0.1	-0.23	36%

EXAMPLE 94 -- Comparative Dissolution Kinetics

The comparative dissolution kinetics of sucrose formulations containing low concentrations of amorphous silica vs. a crystalline sucrose control formulation were studied. The temperature of the stirred vessel was maintained at 37°C (to simulate body temperature). For the control sample, crystalline sugar (sucrose) was milled to approximate the particle size of the silica-sweetener concentrate. 5.0g of the milled sugar was then added to the stirred vessel, which contained 500ml of water, and the concentration of dissolved sugar was monitored over time. Three samples were evaluated against the control sample: Sample A, whose sucrose particles contained 0.1% amorphous silica; Sample B, whose sucrose particles contained 0.25% amorphous silica; and Sample C, whose sucrose particles contained 1% amorphous silica.

Each of the samples was, in turn, introduced to a stirred vessel containing 500ml of water maintained at 37°C (to simulate body temperature). In each of the four tests, a total of 5.0g of sugar was introduced at t=0. For the sweetener particles containing amorphous silica, silica-sweetener concentrate sample, the concentrate of Example 27, whose particles contain 50% amorphous silica and 50% sucrose, was used. 10.0 grams of the concentrate, containing the identical quantity (5.0g) of sucrose with respect to the control sample, was added to a stirred vessel containing 500g of water. The mixing and heating were performed in an identical fashion with respect to the control sample. The results are plotted in Figure 6A.

This procedure, in which the total sugar concentration is 1% by weight, and the well-stirred vessel is maintained at 37°C, is termed the “standard kinetics evaluation procedure”.

EXAMPLE 95 -- Comparative Dissolution Kinetics

The comparative dissolution kinetics of sucrose formulations containing high concentrations of amorphous silica vs. a crystalline sucrose control formulation were studied. The temperature of the stirred vessel was maintained at 37°C. For the control sample, crystalline sugar (sucrose) was milled to approximate the particle size of the silica-sweetener concentrate. 5.0g of the milled sugar was then added to the stirred vessel, which contained 500ml of water, and the concentration of dissolved sugar was monitored over time. For the inventive silica-sweetener concentrate sample, the concentrate of Example 27, whose particles contain 50% amorphous silica and 50% sucrose, was used. 10.0 grams of the concentrate, containing the identical quantity (5.0g) of sucrose with respect to the control sample, was added to a stirred vessel containing 500ml of water. The mixing and heating were performed in an identical fashion with respect to the control sample. The results are plotted in Figure 6B.

EXAMPLES 96-98

Two silica-and-sweetener concentrates: 25:75 and 15:85 silica:sucrose, by weight, were subjected to X-ray diffraction (XRD) using an X-ray Diffractometer (D8 Advance Series II, Bruker). As a control, table sugar was subjected to the identical procedure. The respective diffraction patterns (intensity vs. 2θ) are plotted in Figure 7.

It is evident from the XRD plots of the concentrates that the diffraction patterns of the concentrates exhibit crystalline character, and are qualitatively similar to the diffraction pattern of the crystalline sucrose sample.

It will be appreciated that quantification of the degree of crystallinity, or of the relative quantities of amorphous sweetener vs. crystalline sweetener (e.g., used herein in the specification and in the claims section that follows), may be determined by various analytical procedures known to those skilled in the art, including, but not limited to, the following:

- X-ray powder diffraction (XRPD)
- Isothermal microcalorimeter (IMC)
- Solution calorimetry
- Dynamic vapor sorption (DVS)
- Conventional differential scanning calorimetry (DSC), Modulated temperature DSC (MTDSC), High speedDSC (hyper-DSC)
- Raman spectroscopy
- Near infrared spectroscopy (NIRS)
- Solid state nuclear magnetic resonance (SS-NMR)
- Inverse phase gas chromatography (IGC)
- Density (specific gravity) measurements.

EXAMPLE 99: Exemplary Starch Content Calculation

A cookie is made from fat (palm oil, 17%), white wheat flour (61%), sucrose (11%), a silica-sweetener concentrate of Example 8 (1%), and a fructan (inulin, 10%). The only starch-containing ingredient is the white wheat flour, which contains about 68% starch. Thus, the starch content of the cookie is 68% of 61%, or about 41.5%.

EXAMPLE 100: Exemplary Fat Content Calculation

A hazelnut spread is made from fat (palm oil, 24%), sucrose (28%), a silica-sweetener concentrate of Example 11 (2%), pure hazelnut paste (13%, having a 61% fat content), non-fat milk powder (6%), cocoa powder (7% having a 12% fat content) and a fructan (inulin, 20%). The total fat content of the hazelnut spread is 24% + (61% of 13%) + (12% of 7%), or about 32.8%.

Additional Embodiments

Additional Embodiments 1 to 152 are provided hereinbelow.

Embodiment 1. A formulation comprising:

a first population of sweetener particles containing a plurality of amorphous silica particles within said first population of sweetener particles,

each individual sweetener particle of said sweetener particles containing:

(a) a caloric sweetener; and

(b) at least one amorphous silica particle, disposed in said each individual sweetener particle;

wherein the average particle size (Dv50-P) of said first population is within a range of 20 to 1000 micrometers (μm);

wherein the average particle size (Dv50-S) of said plurality of amorphous silica particles is within a range of 0.8 to 20 micrometers (μm);

wherein the average ratio of the number of said plurality of amorphous silica particles to the number of said sweetener particles is at least 2.5:1;

wherein said first population of sweetener particles is less sweet with respect to a control sweetener identical to said first population of sweetener particles, but devoid of said plurality of amorphous silica particles;

and wherein, when said first population is diluted with sucrose to produce a standard formulation containing 0.1% amorphous silica, said standard formulation exhibits improved sweetness with respect to a corresponding control sucrose formulation identical to said standard formulation, but devoid of said plurality of amorphous silica particles.

Embodiment 2. The formulation of Embodiment 1, wherein said each individual sweetener particle has a sweetener core that is devoid of amorphous silica particles, said

sweetener core having a diameter of at least 7 micrometers (μm), said sweetener core being disposed at least 5 micrometers (μm) from the surface of said each individual sweetener particle.

Embodiment 3. The formulation of Embodiment 2, wherein said diameter of said sweetener core is at least 10 μm .

Embodiment 4. The formulation of Embodiment 2, wherein said diameter of said sweetener core is at least 15 μm .

Embodiment 5. The formulation of Embodiment 2, wherein said diameter of said sweetener core is at least 25 μm .

Embodiment 6. The formulation of Embodiment 2, wherein said diameter of said sweetener core is at least 40 μm .

Embodiment 7. The formulation of Embodiment 2, wherein said diameter of said sweetener core is at least 60 μm .

Embodiment 8. The formulation of any one of Embodiments 1 to 7, wherein the average ratio of the number of said amorphous silica particles to the number of said sweetener particles is at least 3.5:1.

Embodiment 9. The formulation of any one of Embodiments 1 to 7, wherein the average ratio of the number of said amorphous silica particles to the number of said sweetener particles is at least 5:1.

Embodiment 10. The formulation of any one of Embodiments 1 to 7, wherein the average ratio of the number of said amorphous silica particles to the number of said sweetener particles is at least 7:1.

Embodiment 11. The formulation of any one of Embodiments 1 to 7, wherein the average ratio of the number of said amorphous silica particles to the number of said sweetener particles is at least 10:1.

Embodiment 12. The formulation of any one of Embodiments 1 to 7, wherein the average ratio of the number of said amorphous silica particles to the number of said sweetener particles is at least 15:1.

Embodiment 13. The formulation of any one of Embodiments 1 to 12, wherein the average ratio of the number of said amorphous silica particles to the number of said sweetener particles is at most 250:1.

Embodiment 14. The formulation of Embodiment 13, wherein the average ratio of the number of said amorphous silica particles to the number of said sweetener particles is at most 150:1.

Embodiment 15. The formulation of Embodiment 13, wherein the average ratio of the number of said amorphous silica particles to the number of said sweetener particles is at most 100:1.

Embodiment 16. The formulation of any one of the preceding Embodiments, wherein Dv50-P is at least 25 μm .

Embodiment 17. The formulation of Embodiment 16, wherein Dv50-P is at least 30 μm .

Embodiment 18. The formulation of Embodiment 16, wherein Dv50-P is at least 35 μm .

Embodiment 19. The formulation of Embodiment 16, wherein Dv50-P is at least 40 μm .

Embodiment 20. The formulation of Embodiment 16, wherein Dv50-P is at least 50 μm .

Embodiment 21. The formulation of Embodiment 16, wherein Dv50-P is at least 65 μm .

Embodiment 22. The formulation of Embodiment 16, wherein Dv50-P is at least 80 μm .

Embodiment 23. The formulation of Embodiment 16, wherein Dv50-P is at least 100 μm .

Embodiment 24. The formulation of Embodiment 16, wherein Dv50-P is at least 125 μm .

Embodiment 25. The formulation of Embodiment 16, wherein Dv50-P is at least 150 μm .

Embodiment 26. The formulation of any one of the preceding Embodiments, wherein Dv50-S is at least 1 μm .

Embodiment 27. The formulation of Embodiment 26, wherein Dv50-S is at least 1.5 μm .

Embodiment 28. The formulation of Embodiment 26, wherein Dv50-S is at least 2 μm .

Embodiment 29. The formulation of Embodiment 26, wherein Dv50-S is at least 2.5 μm .

Embodiment 30. The formulation of any one of the preceding Embodiments, wherein Dv50-S is at most 15 μm .

Embodiment 31. The formulation of Embodiment 26, wherein Dv50-S is at most 10 μm .

Embodiment 32. The formulation of any one of the preceding Embodiments, wherein a first weight ratio of said plurality of amorphous silica particles to said caloric sweetener is within a range of 0.07:1 to 10:1.

Embodiment 33. The formulation of Embodiment 32, wherein said first weight ratio is at least 0.10:1.

Embodiment 34. The formulation of Embodiment 32, wherein said first weight ratio is at least 0.12:1.

Embodiment 35. The formulation of Embodiment 32, wherein said first weight ratio is at least 0.15:1.

Embodiment 36. The formulation of Embodiment 32, wherein said first weight ratio is at least 0.20:1.

Embodiment 37. The formulation of Embodiment 32, wherein said first weight ratio is at least 0.25:1.

Embodiment 38. The formulation of Embodiment 32, wherein said first weight ratio is at least 0.30:1.

- Embodiment 39. The formulation of Embodiment 32, wherein said first weight ratio is at least 0.35:1.
- Embodiment 40. The formulation of Embodiment 32, wherein said first weight ratio is at least 0.40:1.
- Embodiment 41. The formulation of Embodiment 32, wherein said first weight ratio is at least 0.45:1.
- Embodiment 42. The formulation of Embodiment 32, wherein said first weight ratio is at least 0.5:1.
- Embodiment 43. The formulation of Embodiment 32, wherein said first weight ratio is at least 0.6:1.
- Embodiment 44. The formulation of Embodiment 32, wherein said first weight ratio is at least 0.7:1.
- Embodiment 45. The formulation of Embodiment 32, wherein said first weight ratio is at least 0.8:1.
- Embodiment 46. The formulation of Embodiment 32, wherein said first weight ratio is at least 0.9:1.
- Embodiment 47. The formulation of Embodiment 32, wherein said first weight ratio is at least 1:1.
- Embodiment 48. The formulation of Embodiment 32, wherein said first weight ratio is at least 1.2:1.
- Embodiment 49. The formulation of Embodiment 32, wherein said first weight ratio is at least 1.5:1.
- Embodiment 50. The formulation of Embodiment 32, wherein said first weight ratio is at least 2:1.
- Embodiment 51. The formulation of any one of the preceding Embodiments, wherein within said first population, at least 50%, by number of molecular units of said caloric sweetener, is attached solely to other molecular units of said caloric sweetener.
- Embodiment 52. The formulation of Embodiment 51, wherein at least 60%, by number of molecular units of said caloric sweetener, is attached solely to other molecular units of said caloric sweetener.
- Embodiment 53. The formulation of Embodiment 51, wherein at least 75%, by number of molecular units of said caloric sweetener, is attached solely to other molecular units of said caloric sweetener.

Embodiment 54. The formulation of any one of the preceding Embodiments, wherein at most 50% of said caloric sweetener disposed in said individual sweetener particle is directly attached to any of said at least one amorphous silica particle.

Embodiment 55. The formulation of Embodiment 54, wherein at most 40% of said caloric sweetener disposed in said individual sweetener particle is directly attached to said at least one amorphous silica particle.

Embodiment 56. The formulation of Embodiment 54, wherein at most 30% of said caloric sweetener disposed in said individual sweetener particle is directly attached to said at least one amorphous silica particle.

Embodiment 57. The formulation of Embodiment 54, wherein at most 20% of said caloric sweetener disposed in said individual sweetener particle is directly attached to said at least one amorphous silica particle.

Embodiment 58. The formulation of Embodiment 54, wherein at most 10% of said caloric sweetener disposed in said individual sweetener particle is directly attached to said at least one amorphous silica particle.

Embodiment 59. The formulation of any one of the preceding Embodiments, wherein on an average weight basis that includes all of said individual sweetener particles, at most 50% of said caloric sweetener disposed within each said individual sweetener particle is directly attached to any of said at least one amorphous silica particle within said individual sweetener particle.

Embodiment 60. The formulation of Embodiment 59, wherein at most 40% of said caloric sweetener disposed within each said individual sweetener particle is directly attached to any of said at least one amorphous silica particle within said individual sweetener particle.

Embodiment 61. The formulation of Embodiment 59, wherein at most 30% of said caloric sweetener disposed within each said individual sweetener particle is directly attached to any of said at least one amorphous silica particle within said individual sweetener particle.

Embodiment 62. The formulation of Embodiment 59, wherein at most 20% of said caloric sweetener disposed within each said individual sweetener particle is directly attached to any of said at least one amorphous silica particle within said individual sweetener particle.

Embodiment 63. The formulation of any one of the preceding Embodiments, wherein said caloric sweetener includes a sweetener carbohydrate selected from at least one of the group consisting of sucrose, glucose, fructose, maltose, lactose, mannose, allulose, tagatose, xylose, galactose, arabinose, galactofructose.

Embodiment 64. The formulation of Embodiment 63, wherein said sweetener carbohydrate includes sucrose.

- Embodiment 65. The formulation of Embodiment 63, wherein said sweetener carbohydrate includes glucose.
- Embodiment 66. The formulation of Embodiment 63, wherein said sweetener carbohydrate includes fructose.
- Embodiment 67. The formulation of Embodiment 63, wherein said sweetener carbohydrate predominantly includes sucrose.
- Embodiment 68. The formulation of Embodiment 63, wherein said sweetener carbohydrate predominantly includes glucose.
- Embodiment 69. The formulation of Embodiment 63, wherein said sweetener carbohydrate predominantly includes fructose.
- Embodiment 70. The formulation of any one of the preceding Embodiments, wherein said caloric sweetener includes a sweetener polyol selected from at least one of the group consisting of xylitol, maltitol, erythritol, sorbitol, threitol, arabitol, hydrogenated starch hydrolysates (HSH), isomalt, lactitol, mannitol, and galactitol (dulcitol).
- Embodiment 71. The formulation of any one of the preceding Embodiments, wherein the sweetener formulation is in the form of a particulate solid.
- Embodiment 72. The formulation of Embodiment 71, wherein said particulate solid is a powder.
- Embodiment 73. The formulation of Embodiment 72, wherein said powder is a free-flowing powder.
- Embodiment 74. The formulation of any one of the preceding Embodiments, wherein the ordinary sweetener is a normative ordinary sweetener.
- Embodiment 75. The formulation of any one of the preceding Embodiments, wherein the ordinary sugar is a normative ordinary sugar.
- Embodiment 76. The formulation of Embodiment 75, wherein said normative ordinary sugar includes sucrose.
- Embodiment 77. The formulation of Embodiment 75, wherein said normative ordinary sugar contains at least 65% sucrose, by weight.
- Embodiment 78. The formulation of Embodiment 75, wherein said normative ordinary sugar contains at least 85% sucrose, by weight.
- Embodiment 79. The formulation of Embodiment 75, wherein said normative ordinary sugar contains at least 95% sucrose, by weight.
- Embodiment 79A. The formulation of any one of the preceding Embodiments, wherein a differential in the Comparative Sweetness Index between said standard formulation and said corresponding control sucrose formulation identical to said standard formulation, but devoid of said plurality of amorphous silica particles, is at least 3.

Embodiment 79B. The formulation of Embodiment 79A, wherein said differential is at least 5.

Embodiment 79C. The formulation of Embodiment 79A, wherein said differential is at least 7.

Embodiment 79D. The formulation of Embodiment 79A, wherein said differential is at least 10.

Embodiment 79E. The formulation of Embodiment 79A, wherein said differential is at least 15.

Embodiment 80. A formulation comprising:

a first population of sweetener particles, each individual sweetener particle of said sweetener particles containing

- (a) sweetener particles containing a caloric sweetener; and
- (b) a plurality of amorphous silica particles, disposed in said each individual sweetener particle;

wherein said first population of sweetener particles exhibits slower dissolution kinetics with respect to a control sweetener identical to said first population of sweetener particles, but devoid of said plurality of amorphous silica particles;

and wherein, when said first population is diluted with said caloric sweetener to produce a standard formulation containing 0.1% amorphous silica, said standard formulation exhibits improved sweetness with respect to a corresponding control sweetener formulation identical to said standard formulation, but devoid of said plurality of amorphous silica particles.

Embodiment 80A. A formulation comprising:

a first population of sweetener particles, each individual sweetener particle of said sweetener particles containing

- (a) sweetener particles containing a caloric sweetener; and
- (b) a plurality of amorphous silica particles, disposed in said each individual sweetener particle;

wherein said first population of sweetener particles exhibits slower dissolution kinetics with respect to a control sweetener identical to said first population of sweetener particles, but

- (i) is devoid of said plurality of amorphous silica particles; and
- (ii) is fully crystalline;

and wherein, when said first population is diluted with said caloric sweetener to produce a standard formulation containing 0.1% amorphous silica, said standard formulation exhibits improved sweetness with respect to a corresponding control sweetener formulation identical to said standard formulation, but devoid of said plurality of amorphous silica particles.

Embodiment 80B. A formulation comprising:

a first population of sweetener particles, each individual sweetener particle of said sweetener particles containing

- (a) sweetener particles containing a caloric sweetener; and

- (b) a plurality of amorphous silica particles, disposed in said each individual sweetener particle;

wherein said first population of sweetener particles exhibits slower dissolution kinetics with respect to a control sweetener identical to said first population of sweetener particles, but

- (i) is devoid of said plurality of amorphous silica particles; and
(ii) is fully amorphous;

and wherein, when said first population is diluted with said caloric sweetener to produce a standard formulation containing 0.1% amorphous silica, said standard formulation exhibits improved sweetness with respect to a corresponding control sweetener formulation identical to said standard formulation, but devoid of said plurality of amorphous silica particles.

Embodiment 81. The formulation of any one of Embodiments 1 to 80B, wherein the dissolution kinetics of said first population of sweetener particles is slower with respect to the dissolution kinetics of said control sweetener by at least 5%.

Embodiment 82. The formulation of Embodiment 81, wherein the dissolution kinetics of said first population of sweetener particles is slower by at least 7%.

Embodiment 83. The formulation of Embodiment 81, wherein the dissolution kinetics of said first population of sweetener particles is slower by at least 10%.

Embodiment 84. The formulation of Embodiment 81, wherein the dissolution kinetics of said first population of sweetener particles is slower by at least 12%.

Embodiment 85. The formulation of Embodiment 81, wherein the dissolution kinetics of said first population of sweetener particles is slower by at least 15%.

Embodiment 86. The formulation of Embodiment 81, wherein the dissolution kinetics of said first population of sweetener particles is slower by at least 20%.

Embodiment 87. The formulation of any one of Embodiments 80 to 86, further comprising any of the features, or any combination of the features, of Embodiments 1 to 79E.

Embodiment 100. A formulation comprising:

a first population of sweetener particles, each individual sweetener particle of said sweetener particles containing

- (a) a caloric sweetener; and
(b) at least one amorphous silica particle, disposed in said individual sweetener particle;

wherein the average particle size (Dv50) of said first population is within a range of 20 to 1000 micrometers (μm);

wherein the average particle size (Dv50) of said plurality of amorphous silica particles is within a range of 0.8 to 20 micrometers (μm);

wherein, in at least a fraction of said sweetener particle of said first population of sweetener particles, at most 50% of said caloric sweetener is directly attached to said at least one amorphous silica particle;

wherein said first population of sweetener particles is less sweet with respect to a control sweetener identical to said first population of sweetener particles, but devoid of said plurality of amorphous silica particles;

and wherein, when said first population is diluted with said caloric sweetener to produce a standard formulation containing 0.1% amorphous silica, said standard formulation exhibits improved sweetness with respect to a corresponding control sweetener formulation identical to said standard formulation, but devoid of said plurality of amorphous silica particles.

Embodiment 101. The formulation of Embodiment 100, wherein at most 40% of said caloric sweetener disposed in said individual sweetener particle is directly attached to said at least one amorphous silica particle.

Embodiment 102. The formulation of Embodiment 100, wherein at most 30% of said caloric sweetener disposed in said individual sweetener particle is directly attached to said at least one amorphous silica particle.

Embodiment 103. The formulation of Embodiment 100, wherein at most 20% of said caloric sweetener disposed in said individual sweetener particle is directly attached to said at least one amorphous silica particle.

Embodiment 103A. The formulation of any one of Embodiments 100 to 103, further comprising any of the limitations, or any combination of the limitations, of Embodiments 1 to 87.

Embodiment 104. A formulation comprising:

- (a) a first population of sweetener particles containing a caloric sweetener and amorphous silica particles; and
- (b) caloric sweetener particles;

wherein said caloric sweetener particles make up at least 90% of the formulation, by weight;

wherein said first population of sweetener particles contain said amorphous silica in an intra-particle weight ratio, with respect to said caloric sweetener, within a range of 0.07:1 to 10:1;

and wherein a global weight ratio of total silica within the formulation, to total caloric sweetener within the formulation, is within a range of 0.03% to 2%, by weight;

and wherein said caloric sweetener within said first population of sweetener particles is crystalline or exhibits a crystalline behavior.

Embodiment 104A. The formulation of Embodiment 104, wherein said caloric sweetener contains sucrose.

Embodiment 104B. The formulation of Embodiment 104A, wherein said caloric sweetener contains at least 50% sucrose, by weight.

Embodiment 104C. The formulation of Embodiment 104A, wherein said caloric sweetener contains at least 65% sucrose, by weight.

Embodiment 104D. The formulation of Embodiment 104A, wherein said caloric sweetener contains at least 85% sucrose, by weight.

Embodiment 104B. The formulation of Embodiment 104A, wherein said caloric sweetener contains at least 95% sucrose, by weight.

Embodiment 105. The formulation of any one of Embodiments 104 to 104B, wherein said global weight ratio is within a range of 0.03% to 1.5%.

Embodiment 106. The formulation of Embodiment 104, wherein said global weight ratio is within a range of 0.05% to 1.0%.

Embodiment 107. The formulation of Embodiment 104, wherein said global weight ratio is within a range of 0.05% to 0.7%.

Embodiment 107A. The formulation of Embodiment 104, wherein said global weight ratio is within a range of 0.05% to 0.5%.

Embodiment 108. The formulation of Embodiment 104, wherein said global weight ratio is within a range of 0.05% to 0.35%.

Embodiment 109. The formulation of Embodiment 104, wherein said global weight ratio is within a range of 0.05% to 0.25%.

Embodiment 110. The formulation of Embodiment 104, wherein said global weight ratio is within a range of 0.05% to 0.2%.

Embodiment 111. The formulation of any one of Embodiments 104 to 110, wherein said global weight ratio is at least 0.07%.

Embodiment 112. The formulation of any one of Embodiments 104 to 110, wherein said global weight ratio is at least 0.085%.

Embodiment 113. The formulation of any one of Embodiments 104 to 110, wherein said global weight ratio is at least 0.10%.

Embodiment 114. The formulation of any one of Embodiments 104 to 107, wherein said global weight ratio is at least 0.5%.

Embodiment 115. The formulation of Embodiment 104 or Embodiment 105, wherein said global weight ratio is at least 0.8%.

Embodiment 116. The formulation of Embodiment 104, wherein said global weight ratio is at least 1.2%.

Embodiment 117. The formulation of any one of Embodiments 104 to 116, wherein an amorphous silica concentration within said caloric sweetener particles is at most 0.1% of said caloric sweetener particles, by weight.

Embodiment 118. The formulation of Embodiment 117, wherein said amorphous silica concentration within said caloric sweetener particles is at most 0.02% of said caloric sweetener particles, by weight.

Embodiment 119. The formulation of any one of Embodiments 104 to 116, wherein said caloric sweetener particles make up at least 95% of the formulation, by weight.

Embodiment 120. The formulation of Embodiment 119, wherein said caloric sweetener particles make up at least 98% of the formulation, by weight.

Embodiment 121. The formulation of Embodiment 119, wherein said caloric sweetener particles make up at least 99% of the formulation, by weight.

Embodiment 122. The formulation of Embodiment 119, wherein said caloric sweetener particles make up at least 99.5% of the formulation, by weight.

Embodiment 123. The formulation of any one of Embodiments 104 to 122, wherein said intra-particle weight ratio is at least 0.10:1.

Embodiment 124. The formulation of Embodiment 123, wherein said intra-particle weight ratio is at least 0.12:1.

Embodiment 125. The formulation of Embodiment 123, wherein said intra-particle weight ratio is at least 0.15:1.

Embodiment 126. The formulation of Embodiment 123, wherein said intra-particle weight ratio is at least 0.2:1.

Embodiment 127. The formulation of Embodiment 123, wherein said intra-particle weight ratio is at least 0.25:1.

Embodiment 128. The formulation of Embodiment 123, wherein said intra-particle weight ratio is at least 0.3:1.

Embodiment 129. The formulation of Embodiment 123, wherein said intra-particle weight ratio is at least 0.5:1.

Embodiment 130. The formulation of Embodiment 123, wherein said intra-particle weight ratio is at least 0.7:1.

Embodiment 131. The formulation of Embodiment 123, wherein said intra-particle weight ratio is at least 1:1.

Embodiment 132. The formulation of Embodiment 123, wherein said intra-particle weight ratio is at least 1.2:1.

Embodiment 133. The formulation of Embodiment 123, wherein said intra-particle weight ratio is at least 1.5:1.

Embodiment 134. The formulation of any one of Embodiments 104 to 133, wherein said intra-particle weight ratio is at most 8:1.

Embodiment 135. The formulation of any one of Embodiments 104 to 133, wherein said intra-particle weight ratio is at most 4:1.

Embodiment 136. The formulation of any one of Embodiments 104 to 133, wherein said intra-particle weight ratio is at most 2.5:1.

Embodiment 137. The formulation of any one of Embodiments 104 to 133, wherein said intra-particle weight ratio is at most 1.5:1.

Embodiment 138. An edible formulation comprising:

- (a) the formulation of any one of the preceding Embodiments;
- (b) at least one fat; and
- (c) optionally, at least one starch;

wherein a total concentration of all sweeteners, said at least one fat, and said at least one starch, within the edible formulation, is at least 30%, on a weight basis.

Embodiment 139. The edible formulation of Embodiment 138, wherein a weight content of said all sweeteners within the edible formulation is at least 8%.

Embodiment 140. The edible formulation of Embodiment 138 or Embodiment 139, containing at least 5% of said all sweeteners, and at least 5% of said at least one fat.

Embodiment 141. The edible formulation of any one of Embodiments 138 to 140, containing at least 5% of said all sweeteners, and at least 5% of said at least one starch.

Embodiment 142. The edible formulation of any one of Embodiments 138 to 141, wherein a weight concentration of said all sweeteners is within a range of 10% to 80%.

Embodiment 143. A method of producing the formulation of any one of Embodiments 104 to 142, the method comprising:

- (a) producing said first population of sweetener particles containing said caloric sweetener and said amorphous silica; and
- (b) mixing said sweetener particles with said caloric sweetener particles.

Embodiment 144. The method of Embodiment 143, wherein said caloric sweetener particles include sucrose.

Embodiment 145. The method of Embodiment 143, wherein said caloric sweetener particles predominantly include sucrose.

Embodiment 145A. The method of Embodiment 143, wherein said caloric sweetener particles include at least 65% sucrose.

Embodiment 146. The method of Embodiment 143, wherein said caloric sweetener particles are sucrose or ordinary table sugar.

Embodiment 147. A method of producing a food, the method comprising:

- (a) providing the formulation of any one of Embodiments 1 to 103; and
- (b) mixing said sweetener particles with a caloric sweetener such as an ordinary caloric sweetener, at least one fat, and optionally, at least one starch.

Embodiment 148. The method of Embodiment 147, wherein a total concentration of all sweeteners, said at least one fat, and said at least one starch, within the food, is at least 30%, on a weight basis.

Embodiment 148A. The method of Embodiments 147 or 148, wherein said caloric sweetener is an ordinary caloric sweetener.

Embodiment 149. The method of any one of Embodiments 147 to 148A, wherein said mixing includes mixing said sweetener particles with said at least one starch.

Embodiment 150. The method of any one of Embodiments 147 to 149, wherein said sweetener includes sucrose.

Embodiment 151. The method of any one of Embodiments 147 to 149, wherein said sweetener predominantly includes sucrose.

Embodiment 152. The method of any one of Embodiments 147 to 149, wherein said sweetener is sucrose.

As used herein, the term “sweetener carbohydrate” refers to a nutritive or caloric sweetener having at least one carbohydrate moiety, which carbohydrate is processed by the human body to produce energy. A sweetener carbohydrate produces a sweet taste when consumed by the typical human consumer. If, on a normalized sweetness scale, on a weight basis, in which sucrose is taken as a standard of 1, maltose is about 0.31, and lactose is about 0.22, the term “sweetener carbohydrate” would apply to lactose, and to any sugar or other nutritive, carbohydrate-containing sweetener having a sweetness within a range of 0.15 to 2.5 on this normalized sweetness scale. Alternatively, it may be stated that the minimum sweetness for the sugar or other nutritive, carbohydrate-containing sweetener would be that of raffinose (which has a sweetness of 0.15 on the above-mentioned scale). More typically, such a sweetener carbohydrate has a sweetness within a range of 0.25 to 2.5, 0.35 to 2.5, 0.45 to 2.5, 0.25 to 1.8, 0.45 to 1.7, 0.15 to 1.7, or 0.35 to 1.5 on this normalized sweetness scale.

It is noted that the relative sweetness of fructose reported in the literature has been reported to be as little as 0.91, and as much as about 1.7. For the avoidance of doubt, the term “sweetener carbohydrate” is meant to include fructose, irrespective of any of its reported relative sweetness values.

As used herein, the term “normalized sweetness scale”, refers to a relative sweetness scale, on a weight basis, in which sucrose is assigned a value of 1.00. More specifically, the normalized sweetness scale is determined according to the methods disclosed in Moscowitz, H. “Ratio Scales of Sugar Sweetness”; Perception & Psychophysics, 1970, Vol. 7 (5), in which the power function for the sugars and polyols/sugar alcohols has an exponent of 1.3 ($n = 1.3$), as disclosed therein in Table 3, and as provided hereinbelow.

From “Ratio Scales of Sugar Sweetness”

	Percent by Weight Basis	
	Rank	Relative Sweetness
Sucrose	1	1.00
Fructose	2	0.91
Raftinose	15	0.15
Maltose	12	0.31
Lactose	14	0.22
Dulcitol	5	0.46
Glucose	4	0.45
Galactose	6	0.42
Sorbose	7	0.41
Sorbitol	9	0.37
Mannitol	11	0.33
Arabinose	8	0.39
Rhamnose	10	0.35
Glycerol	3	0.50
Xylose	13	0.26

A sweetener carbohydrate may be a monosaccharide or a disaccharide. Examples of sweetener carbohydrates include, but are not limited to, sucrose, glucose, maltose, fructose, lactose, or any combination of sweetener carbohydrates. One or more sweetener carbohydrate may be combined with one or more sweetener polyols. A sweetener carbohydrate may be naturally occurring or synthetically produced.

As used herein, the term “sweetener polyol” refers to a consumable polyol that produces a sweet taste when consumed by the typical human consumer. Non-limiting examples of sweetener polyols include xylitol, maltitol, erythritol, sorbitol, threitol, arabitol, hydrogenated starch hydrolysates (HSH), isomalt, lactitol, mannitol, or galactitol (dulcitol). In many instances, the polyol is a sugar alcohol. A sugar alcohol can be produced from a carbohydrate by any known method of reduction (via a chemical or biological transformation) of an acid or aldehyde to an alcohol. In other cases, a sweetener polyol can be synthesized from a parent carbohydrate. Alternatively, a sweetener polyol may be obtained from a biological source.

For the avoidance of doubt, the term “sweetener polyol” is meant to include any polyol/sugar alcohol having a sweetness within a range of 0.15 to 2.5 on the above-described normalized sweetness scale. More typically, such a sweetener polyol has a sweetness within a range of 0.15 to 1.5, 0.15 to 1.0, 0.15 to 0.8, 0.15 to 0.7, 0.20 to 0.7, 0.15 to 0.6, or 0.25 to 0.6, on this normalized sweetness scale.

Average particle size (D50) may be based on the number of particles in the population (“D_N50”) or may be based on the volume of particles (D_V50). These measurements may be obtained by various known methods including static light scattering (SLS), dynamic light scattering (DLS), sieving, and various methods of microscopy. Some methods may be preferred for larger ranges of particles, others may be preferred for smaller ranges of particles.

As used herein in the specification and in the claims section that follows, the term “specific surface area”, with respect to a silica, refers to a Brunauer–Emmett–Teller (BET) method according to ISO Standard 9277.

As used herein in the specification and in the claims section that follows, the term “starch” is meant to include edible starches that are used or may be used in foodstuffs. Typically, such starches include at least one of amylose and amylopectin, and more typically, both amylose and amylopectin. It will be appreciated that various modifications of starch may be made, in order to impart to a particular foodstuff, or to the starch therein, specific chemical and/or physical properties, including, by way of example, the prevention of gelling at cold temperatures, withstanding low pH, or resistance to high shear or to high temperatures.

Often, starch is present in an ingredient, *e.g.*, flour. In white wheat flour, the starch content is typically about 68%. In oats, the starch content is typically about 58%.

In addition to including fats that are solid at room temperature (25°C), *e.g.*, beef fat, shortening, palm oil, and butter, as used herein in the specification and in the claims section that follows, the term “fat” is meant to include edible oils, including those that are liquid at room temperature, *e.g.*, cooking oils. Specific examples of edible oils are olive oil, walnut oil, corn oil, and cottonseed oil.

Fats may be a separate ingredient, or may be an ingredient within a food ingredient. For example, hazelnut paste and cocoa powder both contain fat.

As used herein in the specification and in the claims section that follows, the term “ordinary sweetener” and the like refers to a caloric sweetener containing at most 0.08% amorphous silica, and more typically, at most 0.05%, at most 0.02%, or at most 0.01%. Yet more typically, the ordinary sweetener is a “normative” ordinary sweetener that contains at most 0.005% amorphous silica, on a dry weight basis, or is substantially devoid or devoid of such amorphous silica.

Typically, the ordinary sweetener is crystalline or exhibits crystalline behavior. A “normative” ordinary sweetener is crystalline and always exhibits crystalline behavior.

As used herein in the specification and in the claims section that follows, the term “ordinary sugar”, and the like, refers to an ordinary sweetener whose caloric sweetener content is made up of at least 90% crystalline sucrose, on a dry weight basis. More typically, the caloric sweetener content is at least 95%, at least 98%, or at least 99% crystalline sucrose, on this dry weight basis.

In “ordinary sweetener” and “ordinary sugar”, the caloric sweetener content, by weight, is at least 80%, and more typically, at least 90%, at least 95%, or at least 98%.

As used herein in the specification and in the claims section that follows, the term “table sugar” refers to crystalline sucrose having a D50 within the range of 300-1000 micrometers (using sieve characterization or by other conventional means known to those of skill in the art).

As used herein in the specification and in the claims section that follows, the term “dissolution kinetics” refers to the kinetics of dissolution as measured in the standard kinetics evaluation procedure provided in Examples 94 and 95.

As used herein in the specification and in the claims section that follows, the term “identical”, with respect to two formulations, means that both the chemical composition and the particle size distribution are substantially the same for the two formulations, as would be understood by those of skill in the art.

As used herein in the specification and in the claims section that follows, the term “exhibits improved sweetness” with respect to a formulation such as a “standard formulation”, refers to improved sweetness as determined by comparative sensory evaluation, using the Comparative Sweetness Index of Example 85 (minimum of 10 trained panelists). Typically, the improved sweetness will be manifested by a CSI differential of at least 3, or at least 5, and more typically, at least 7, at least 10, at least 12, at least 15, or at least 20.

The comparative sensory evaluation is performed on any one of the following: the standard formulation itself (compared with the “corresponding control sucrose formulation identical to the standard formulation, but devoid of the plurality of amorphous silica particles”); or the standard formulation incorporated into the Type II reduced-sugar muffin, butter cookie, or hazelnut spread of Examples 82B, 83A, and 84A. The “corresponding control sucrose formulation identical to the standard formulation, but devoid of the plurality of amorphous silica particles” is similarly incorporated into the same Type II reduced-sugar muffin, butter cookie, or hazelnut spread, for the comparative sensory evaluation.

As used herein in the specification and in the claims section that follows, the term “percent”, or “%”, refers to percent by weight, unless specifically indicated otherwise. However,

with specific regard to formulations containing silica and at least one sweetener, the weight-percent of the silica is with respect to the sweetener. By way of example, in such a formulation containing 1.3 grams silica dispersed in a syrup containing 650 grams sucrose and 350 grams water, the weight-percent of silica is $1.3/650 = 0.2\%$.

Similarly, the term “ratio”, as used herein in the specification and in the claims section that follows, refers to a weight ratio, unless specifically indicated otherwise.

The modifier "about" and “substantially” used in connection with a quantity is inclusive of the stated value and has the meaning dictated by the context (for example, it includes at least the degree of error associated with the measurement of the particular quantity). When used with a specific value, it should also be considered as disclosing that value.

As used herein in the specification and in the claims section that follows, the term “predominant”, “predominantly”, and the like, *e.g.*, with respect to a sweetener, refers to the sweetener having the highest concentration, by weight.

In the context of the present application and claims, the phrase "at least one of A and B" is equivalent to an inclusive "or", and includes any one of "only A", "only B", or "A and B". Similarly, the phrase "at least one of A, B, and C" is equivalent to an inclusive "or", and includes any one of "only A", "only B", "only C", "A and B", "A and C", "B and C", or "A and B and C".

It will be appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention, which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable sub-combination.

Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. Accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims. All publications, patents and patent applications mentioned in this specification are herein incorporated in their entirety by reference into the specification, to the same extent as if each individual publication, patent or patent application was specifically and individually indicated to be incorporated herein by reference. In addition, citation or identification of any reference in this application shall not be construed as an admission that such reference is available as prior art to the present invention.

WHAT IS CLAIMED IS:

1. A formulation comprising:
a first population of sweetener particles containing a plurality of amorphous silica particles within said first population of sweetener particles,
each individual sweetener particle of said sweetener particles containing:
 - (a) a caloric sweetener; and
 - (b) at least one amorphous silica particle, disposed in said each individual sweetener particle;wherein the average particle size (Dv50-P) of said first population is within a range of 20 to 1000 micrometers (μm);
wherein the average particle size (Dv50-S) of said plurality of amorphous silica particles is within a range of 0.8 to 20 micrometers (μm);
wherein the average ratio of the number of said plurality of amorphous silica particles to the number of said sweetener particles is at least 2.5:1;
wherein said first population of sweetener particles is less sweet with respect to a control sweetener identical to said first population of sweetener particles, but devoid of said plurality of amorphous silica particles;
and wherein, when said first population is diluted with sucrose to produce a standard formulation containing 0.1% amorphous silica, said standard formulation exhibits improved sweetness with respect to a corresponding control sucrose formulation identical to said standard formulation, but devoid of said plurality of amorphous silica particles.
2. The formulation of claim 1, wherein said each individual sweetener particle has a sweetener core that is devoid of amorphous silica particles, said sweetener core having a diameter of at least 7 micrometers (μm), said sweetener core being disposed at least 5 μm from the surface of said each individual sweetener particle.
3. The formulation of claim 2, wherein said diameter of said sweetener core is at least 40 μm .
4. The formulation of any one of claims 1 to 3, wherein the average ratio of the number of said amorphous silica particles to the number of said sweetener particles is at least 7:1.
5. The formulation of any one of the preceding claims, wherein Dv50-P is at least 65 μm .
6. The formulation of any one of the preceding claims, wherein Dv50-S is at least 1 μm .

7. The formulation of any one of the preceding claims, wherein a first weight ratio of said plurality of amorphous silica particles to said caloric sweetener is within a range of 0.07:1 to 10:1.
8. The formulation of claim 7, wherein said first weight ratio is at least 0.6:1.
9. The formulation of any one of the preceding claims, wherein within said first population, at least 50%, by number of molecular units of said caloric sweetener, is attached solely to other molecular units of said caloric sweetener.
10. The formulation of any one of the preceding claims, wherein the sweetener formulation is in the form of a particulate solid.
11. The formulation of any one of the preceding claims, wherein the ordinary sweetener is a normative ordinary sweetener.
12. The formulation of any one of the preceding claims, wherein a differential in the Comparative Sweetness Index between said standard formulation and said corresponding control sucrose formulation identical to said standard formulation, but devoid of said plurality of amorphous silica particles, is at least 3.
13. The formulation of any one of the preceding claims, wherein said first population of sweetener particles exhibits slower dissolution kinetics with respect to a control sweetener identical to said first population of sweetener particles, but
 - (i) is devoid of said plurality of amorphous silica particles; and
 - (ii) is fully crystalline.
14. The formulation of any one of claims 1 to 13, wherein said first population of sweetener particles exhibits slower dissolution kinetics with respect to a control sweetener identical to said first population of sweetener particles, but
 - (i) is devoid of said plurality of amorphous silica particles; and
 - (ii) is fully amorphous.
15. The formulation of claim 13 or 14, wherein the dissolution kinetics of said first population of sweetener particles is slower with respect to the dissolution kinetics of said control sweetener by at least 7%.
16. The formulation of any one of the preceding claims, further comprising caloric sweetener particles.

17. The formulation of claim 16, wherein said caloric sweetener particles make up at least 90% of the formulation, by weight;
wherein said first population of sweetener particles contain said amorphous silica particles in an intra-particle weight ratio, with respect to said caloric sweetener, within a range of 0.07:1 to 10:1;
wherein a global weight ratio of total silica within the formulation, to total caloric sweetener within the formulation, is within a range of 0.03% to 2%, by weight;
and wherein said caloric sweetener within said first population of sweetener particles is crystalline or exhibits a crystalline behavior.
18. The formulation of any one of the preceding claims, wherein said caloric sweetener contains at least 85% sucrose, by weight.
19. The formulation of any one of claims 16 to 18, wherein an amorphous silica concentration within said caloric sweetener particles is at most 0.02% of said caloric sweetener particles, by weight.
20. The formulation of any one of claims 16 to 19, wherein said caloric sweetener particles make up at least 95% of the formulation, by weight.
21. A method of producing the formulation of any one of claims 16 to 20, the method comprising:
- (a) producing said first population of sweetener particles containing said caloric sweetener and said amorphous silica; and
 - (b) mixing said first population of sweetener particles with said caloric sweetener.
22. A formulation comprising:
- (a) the formulation of any one of claims 16 to 20;
 - (b) at least one fat; and
 - (c) optionally, at least one starch;
- wherein a total concentration of all sweeteners, said at least one fat, and said at least one starch, within the edible formulation, is at least 30%, on a weight basis.
23. The formulation of claim 22, wherein a weight concentration of said all sweeteners is within a range of 10% to 80%.