

LOW-FAT OR FAT-FREE AIR BUBBLE-CONTAINING EMULSION

CROSS-REFERENCE TO RELATED APPLICATION

[0001]

5 The application is based upon and claims the benefit of priority from the prior Japanese Patent Application No. 164013/2012, filed on July 24, 2012; the entire contents of which are incorporated herein by reference.

10 BACKGROUND OF THE INVENTION

[0002]

Field of Invention

 The present invention relates to a low-fat or fat-free air bubble-containing emulsion comprising a whey protein aggregate, and a process for producing the same.

15

[0003]

Background Art

 Recently, health trend of consumers is increasing, and there is an trend that low-calorie, low-fat content drinking and food products are likely to be preferred. In air bubble-containing emulsions such as ice creams, however, since fat ingredients contained in air bubble-containing emulsions greatly affect flavor and physical properties, a reduction in fat content is less likely to be accepted by consumers from the viewpoint of preference. In particular, overrun (OR), that is, air inclusion (air content), cannot be satisfactorily ensured, posing a problem that final products (also referred to simply as "products") cannot maintain shape retaining (also referred to as "shape retention").

25

[0004]

30 Therefore, in low-fat (type) ice creams, in order to reduce the fat content while maintaining physical properties, various stabilizers or emulsifiers have been added to enhance overrun. Ice creams containing these stabilizers or emulsifiers disadvantageously sometimes suffer from poor meltability in the mouth and artificial flavor or food feeling derived from stabilizers or emulsifiers causative of bitterness.

35

[0005]

For example, Japanese Patent Application Laid-Open No. 107759/1996 (patent document 1) discloses, as a production process of ice creams that does not require the use of stabilizers, an ice cream in which a heat-denatured whey protein obtained by heating a whey protein solution at such a protein concentration that, when the solution is heated, does not cause aggregation is used as a texture stabilizer, and a process for producing the same. However, the ice cream that is exemplified in this document contains 12% of milk fat, and air bubble-containing emulsions having a low fat content are not described at all.

[0006]

On the other hand, a process for producing an ice cream having a low fat content that possesses creamy flavor and physical properties similar to ice creams having a fat content of about 8 to 10% has been developed by adding a whey protein (a low-fat material) as an alternative to fat to an ice cream mix. For example, Japanese Patent Application Laid-Open No. 255046/1990 (patent document 2) discloses a process for producing frozen desserts that includes adding a whey protein concentrate (WPC) to a fat-free ice cream mix containing stabilizers or emulsifiers. Japanese Patent Application Publication No. 071448/1995 (patent document 3) discloses a non-fat ice cream using a whey sour gel obtained by heating a whey protein concentrate and mildly acidifying the whey protein concentrate with at least one selected from the group consisting of lactobacillus, yeasts, and gluconic lactones, and a process for producing the same. Further, Japanese Patent Application Publication No. 110204/1995 (patent document 4) discloses a process for producing an ice cream using a frozen gel obtained by heating a whey protein concentrate and freezing the heated whey protein concentrate. In these methods, however, since the addition of stabilizers or emulsifiers is indispensable, artificial flavor and food feeling derived from stabilizers or emulsifiers stay in the ice creams obtained by these methods. In the process in which the whey protein concentrate is added, thickening occurs in

heat sterilization, disadvantageously leading to burning to a sterilization machine and an increased internal pressure of piping. Accordingly, the process is unsuitable for efficient continuous production. Further, in the process using the whey sour gel or
5 the frozen gel, the provision of a fermentation step or a freezing step is necessary, and, thus, there is a possibility of rendering the process complicated.

[0007]

Published Japanese Translation of PCT International
10 Publication No. 509475/1994 (patent document 5) discloses that spherical agglomerates of dry microparticulated proteins can be an alternative to fat. In this document, however, the utilization thereof to air bubble-containing emulsions such as ice creams has not been discussed at all. Further, there is no description on
15 overrun properties of air bubble-containing emulsions having a low fat content.

PRIOR ART DOCUMENTS

Patent Documents

20 [0008]

Patent document 1: Japanese Patent Application Laid-Open No. 107759/1996

Patent document 2: Japanese Patent Application Laid-Open No. 255046/1990

25 Patent document 3: Japanese Patent Application Publication No. 071448/1995

Patent document 4: Japanese Patent Application Publication No. 110204/1995

Patent document 5: Published Japanese Translation of PCT
30 International Publication No. 509475/1994

SUMMARY OF THE INVENTION

[0009]

Thus, whey proteins subjected to such various processing
35 treatments exist. However, there is no description on low-fat or fat-free air bubble-containing emulsions having a fat content low

enough to ensure high overrun without adding emulsions or stabilizers. In fact, the present inventors have confirmed that, when an ice cream having a low fat content is produced using a whey protein concentrate as a whey protein subjected to processing treatment and known Simplese 100 (diameter: about 0.1 to 3.0 μm , mean 1 μm) (Products Simplese 100 (Simplese (trademark) 100), see URL: <http://www.sameigenffi.co.jp/indexa/hyd3.html>) as a commercially available product of the spherical agglomerates of dry microparticulated proteins, in the former, extreme thickening occurs in heat sterilization (see Example 6 in working examples that will be described later) and, in the latter, desired overrun cannot be ensured (see Example 2 (2) in working examples that will be described later).

[0010]

The present inventors have now unexpectedly found that, when whey protein aggregates that are obtained by subjecting a whey protein solution to non-conventional processing treatment, that is, simultaneously subjecting the whey protein solution to heating treatment and mechanical shearing treatment and contain particles having a 50% mean particle diameter of 2 to 10 μm are added to an ice cream mix having a low fat content, a high level of overrun can be ensured without the addition of stabilizers and emulsifiers that have been necessary in the prior art, and the product can maintain a shape retention as a final product. As a result, the present inventors have succeeded in producing low-fat or fat-free ice creams having a good flavor or food feeling. Further, the present inventors have found that the whey protein aggregates do not cause thickening in the heat sterilization step, and the present inventors have also succeeded in continuously producing ice creams with a high efficiency. The present invention has been made based on such finding.

[0011]

Thus, an object of the present invention is to provide a low-fat or fat-free air bubble-containing emulsion that can ensure a high level of overrun and has good flavor and food feeling

substantially without the need to use stabilizers and emulsifiers.
[0012]

According to one aspect of the present invention, there is provided a low-fat or fat-free air bubble-containing emulsion comprising, a whey protein aggregate as an alternative to fat, wherein the whey protein aggregate is produced by simultaneously subjecting a whey protein solution to heat treatment and mechanical shearing treatment, and wherein the whey protein aggregate contains particles having a 50% mean particle diameter of 2 to 10 μm .
[0013]

In a preferred embodiment of the present invention, the whey protein aggregate is prepared under such conditions that the heat treatment is carried out at 75 to 85°C for 5 to 10 minute.
[0014]

In a preferred embodiment of the present invention, the whey protein solution has a solid content concentration of 5 to 20% by weight.
[0015]

In a preferred embodiment of the present invention, the air bubble-containing emulsion is a food.
[0016]

In a preferred embodiment of the present invention, the food is one selected from the group consisting of ice creams, ice confectioneries, frozen yogurts, whip creams, margarines, spreads, and whip-type soft cheeses.
[0017]

According to one aspect of the present invention, there is provided a process for producing a low-fat or fat-free air bubble-containing emulsion, the process comprising:

mixing a whey protein aggregate that is produced by simultaneously subjecting a whey protein solution to heat treatment and mechanical shearing treatment and contains particles having a 50% mean particle diameter of 2 to 10 μm , into water and

stirring the mixture to form air bubbles.

[0018]

According to another aspect of the present invention, there is provided a process for producing a low-fat or fat-free ice cream, ice confectionery, or frozen yogurt, the process comprising:

5 mixing a whey protein aggregate that is produced by simultaneously subjecting a whey protein solution to heat treatment and mechanical shearing treatment and contains particles having a 50% mean particle diameter of 2 to 10 μm , into water and

10 stirring and freezing the mixture to form air bubbles.

[0019]

In a preferred embodiment of the present invention, the air bubbles are formed at a temperature of -2.5°C or below.

[0020]

15 In a preferred embodiment of the present invention, in the above production process, the whey protein aggregate is used as an alternative to fat without drying.

[0021]

20 The present invention can provide a low-fat or fat-free air bubble-containing emulsion that can ensure a high level of overrun and has good flavor and food feeling substantially without the need to use stabilizers and emulsifiers and, as a final product, can maintain a shape retention, and a process for producing the same. Also, the whey protein aggregate used in the present
25 invention does not cause thickening even in the heat sterilization step and, thus, a process for continuously producing air bubble-containing emulsions with high efficiency can be provided. Further, the whey protein aggregate according to the present invention is composed mainly of natural food ingredients and can
30 be prepared by simple treatment, that is, by simultaneously performing heat treatment and mechanical shearing treatment without use of pH adjustors, and, thus, the product provided by the present invention is a product that is substantially free from stabilizers and emulsifiers, as well as from other synthetic
35 additives, and has a high natural image.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022]

[Fig. 1] Fig. 1 is a typical view of a rotation portion of a homomixer (T.K.HOMO MIXER MARKII Model 2.5, manufactured by PRIMIX Corporation).

[Fig. 2] Fig. 2 is a graph showing overrun properties (OR%) of a fat-free ice cream with a whey protein aggregate (MP) described in Example 2 (1) mixed thereinto (added thereto).

[Fig. 3] Fig. 3 is a graph showing overrun properties of a fat-free ice cream with MP described in Example 2 (1) mixed thereinto at various concentrations.

[Fig. 4] Fig. 4 is a graph showing overrun properties of a fat-free ice cream with various whey proteins described in Example 2 (2) mixed thereinto.

[Fig. 5] Fig. 5 is a graph showing overrun properties of a fat-free ice cream into which MP with a fat-free milk solid (SNF) described in Example 2 (3) mixed thereinto at various concentrations has been mixed.

[Fig. 6] Fig. 6 is a graph showing overrun properties of a fat-free ice cream into which MP that is described in Example 2 (4) and has been adjusted to various pH values has been mixed.

[Fig. 7] Fig. 7 is a graph showing overrun properties of a low-fat ice cream into which a whey protein aggregate (MP) described in Example 3 has been mixed at various concentrations.

[Fig. 8] Fig. 8 is a photograph showing the results of a meltability test of a low-fat or fat-free ice cream into which a whey protein aggregate (MP) described in Example 4 has been mixed.

[Fig. 9] Fig. 9 is a graph showing the results of a heat resistance comparison test of an ice cream mix (a mixed solution) into which various whey proteins described in Example 6 have been mixed.

DETAILED DESCRIPTION OF THE INVENTION

[0023]

35 Low-fat or fat-free air bubble-containing emulsion

The low-fat or fat-free air bubble-containing emulsion

according to the present invention contains, as an alternative to fat, a whey protein aggregate including particles with a 50% mean particle diameter of 2 to 10 μm obtained by simultaneously
5 subjecting a whey protein solution to heating treatment and mechanical shearing treatment.

[0024]

The whey protein solution used in the present invention is obtained by mixing, dissolving and/or dispersing a whey protein concentrate into water. Here milk or other milk products having
10 a high water content may be used as a substitute for water or may be used in combination with water. In this case, a defatted milk is preferred from the viewpoint of regulating an actually obtained whey protein aggregate to a low fat content.

[0025]

15 The whey protein concentrate (WPC) means a concentrate that is obtained by concentrating a whey protein to a designed predetermined concentration, for example, by membrane treatment and is also called a milk serum protein concentrate. For example, cheese whey-derived WPC and lactic acid
20 whey-derived WPC may be mentioned as WPC used in the present invention. The origin, protein content (degree of concentration) and the like thereof are not particularly limited. Whey protein purification products (WPIs) having a high degree of refining may be used instead of WPC. These may be produced by an ordinary
25 method, or alternatively may be a commercially available product.

[0026]

The composition of a whey protein concentrate (WPC) may be varied, for example, by raw materials, products, and preparation methods of whey. In WPC used in the present
30 invention, in order that the final product (final material) contemplated in the present invention is a low-fat or fat-free air bubble-containing emulsion, the fat content is not more than 5% by weight, preferably not more than 3% by weight, more preferably not more than 1% by weight. Further, in WPC used in
35 the present invention, in order that lactose contained in WPC functions to suppress particulation of whey protein, the lactose

content is not more than 90% by weight, preferably not more than 80% by weight, still more preferably not more than 70% by weight. WPC used in the present invention may be, for example, WPC obtained by concentrating protein to a content of 34% by weight of total and performing desalting (hereinafter referred to as "WPC34"). WPC used in the present invention, however, is not limited thereto.

[0027]

In order to prepare a whey protein solution, in the step of mixing, dissolving and/or dispersing a whey protein concentrate (WPC) into water, heating treatment at a temperature of below 55°C and, if necessary, mechanical shearing treatment with a stirrer, a mixer, powblender or the like may be carried out from the viewpoint of enhancing dissolution efficiency and/or dispersion efficiency for a mixture of WPC with water.

[0028]

Milk products containing a whey protein before concentrating the whey protein, for example, whey powders, non-powdered liquid or sticky paste-like wheys, or concentrated wheys may be used as the whey protein solution used in the present invention.

[0029]

Here, for example, when a WPC powder (WPC34) that has a protein content of 34% by weight and a lactose content of 55% by weight and is obtained by regulating the content (concentration) of protein and the content of lactose as the concentration of solid content in the whey protein solution so as to correspond to a powdered skimmed milk and spray-drying the solution is used, the amount of the WPC powder may be 5 to 20% by weight, preferably 7 to 20% by weight, more preferably 7 to 18% by weight, still more preferably 8 to 18% by weight, still more preferably 9 to 18% by weight. Here the solid component means a component other than water contained in the whey protein solution, specifically a milk component. The milk component includes a not fat milk solid component (SNF) and a fat component. Since the final product (final material)

contemplated in the present invention is a low-fat or fat-free air bubble-containing emulsion, the solid component used in the present invention has a fat content of not more than 5% by weight, preferably not more than 3% by weight, more preferably not more than 1% by weight. When the solid content concentration is not less than 25% by weight, there is a tendency that the whey protein aggregate is not obtained (non-agglomerate) or that the 50% mean particle diameter of particles contained in the actually obtained whey protein aggregate is reduced.

10 [0030]

The content (concentration) of the protein in the whey protein solution may be 0.5 to 20% by weight, preferably 1 to 10% by weight, more preferably 2.5 to 6.5% by weight, still more preferably 3 to 6% by weight, still more preferably 1 to 5% by weight. The content of the protein may be calculated, for example, based on publicly known information, or alternatively may be calculated by measurement according to a publicly known or commonly used method such as a Kjeldahl method.

[0031]

20 The ratio of the content (concentration) of protein in the whey protein solution to the content (concentration) of lactose is preferably 1 to 9 : 9 to 1, more preferably 2 to 6 : 8 to 4. Here the content of lactose may be calculated based on publicly known information, or alternatively may be determined by calculation after measurement according to a publicly known or commonly used method such as liquid chromatography or enzyme kit. When the content of the protein is higher than the content of lactose, the yield of the aggregate of the whey protein per unit is lowered. On the other hand, when the content of lactose is higher than the content of the protein, the aggregation of the whey protein to produce an aggregate is likely to rapidly occur.

30 [0032]

The heating treatment used in the present invention can be performed by any method without particular limitation as long as heating treatment can be performed simultaneously with mechanical shearing treatment. For example, general heating

treatment apparatuses adopted in food processing techniques may be used. Examples of such apparatuses include jacketed tanks, plate-type heat exchangers, tube-type heat exchangers, scraping-type heat exchangers, steam injection-type heaters, and electrical heaters. The temperature of the heating treatment may be 55°C or above, preferably 55°C to 100°C, more preferably 70 to 90°C, still more preferably 75 to 85°C, still more preferably 75 to 80°C. When the temperature of the heating treatment is 75 to 85°C, the time of the heating treatment may be 5 to 20 minute, preferably 5 to 15 minute, more preferably 5 to 10 minute.

[0033]

The mechanical shearing treatment may be carried out in the present invention by any method without particular limitation as long as the shearing treatment can be performed simultaneously with heating treatment. For example, general mechanical shearing treatment apparatuses adopted in food processing techniques may be used. Such apparatuses include, for example, turbo mixers (manufactured by Scanima) and homo mixers (manufactured by PRIMIX Corporation). Regarding the shearing force in the mechanical shearing treatment, for example, when homo mixers (T.K.HOMO MIXER MARKII, Model 2.5, manufactured by PRIMIX Corporation) are used, the rotation speed may be 100 to 10000 rpm, preferably 200 to 8000 rpm, more preferably 250 to 5000 rpm, from the viewpoint of avoiding an excessively small diameter. Here 100 to 10000rpm, 200 to 8000rpm, and 250 to 5000 rpm in the rotation speed of the homo mixer correspond to 1.9 to 190 Pa, 3.7 to 150 Pa, and 4.7 to 94 Pa in terms of shearing force (shearing stress), respectively. That is, the shearing force in the mechanical shearing treatment may be 1.9 to 190 Pa, preferably 3.7 to 150 Pa, more preferably 4.7 to 94 Pa. Since the shearing force in the mechanical shearing treatment greatly varies depending upon setting of the type (model) of actually used shearing treatment apparatuses and the capacity (operation conditions), a person having ordinary skill in the art can attain the effect of the present invention by properly

varying the model, operation conditions and the like.

[0034]

In the present invention, the expression "simultaneously
subjecting" as used herein means that heat treatment and
5 mechanical shearing treatment are simultaneously carried out.

[0035]

The expression "whey protein aggregate" as used herein
means agglomerates of particles that are composed mainly of a
whey protein and are obtained by simultaneously subjecting a
10 why protein solution to heating treatment and mechanical
shearing treatment, the particles having a 50% mean particle
diameter of 2 to 10 μm .

[0036]

Here the 50% mean particle diameter may be measured
15 with a particle size measuring apparatus based on a laser
diffraction/scattering method. In the present invention, the
50% mean particle diameter is preferably measured, for example,
with a particle size distribution measuring apparatus (by a laser
diffraction/scattering method) LS230 (manufactured by Beckman
20 Coulter, Inc.) or a laser diffraction-type particle size distribution
measuring apparatus SALD-2001 system (manufactured by
Shimadzu Seisakusho Ltd.), because the 50% mean particle
diameter can be measured in a simple and cost-effective manner
and the general-purpose property is high. In the present
25 invention, the expression "50% mean particle diameter" as used
herein means a particle diameter that occupies 50% of the whole
particles in terms of cumulative value in the results of a particle
size distribution of a dispersion measured with a particle size
measuring apparatus based on a laser diffraction/scattering
30 method. Specifically, the 50% mean particle diameter means a
particle diameter at a point where the total number of particles
reaches 50% when the number of particles is added in increasing
order of the particle diameter in the particle size distribution.

[0037]

35 Here the 50% mean particle diameter is also called a mean
fat spherical diameter in milk products such as cow milks and milk

beverages, and the expression "50% mean particle diameter" as used herein connotes an expression of a mean fat spherical diameter.

[0038]

5 In the whey protein aggregate used in the present invention, when many particles having a diameter of not more than 1 μm are contained, the stability of overrun of actually obtained air bubble-containing emulsions is so low that the shape retention cannot be maintained.

10 [0039]

 The whey protein aggregates including particles having a 50% mean particle diameter of 2 to 10 μm can be prepared, for example, by simultaneously subjecting a whey protein solution to heating treatment of 75 to 85°C and mechanical shearing
15 treatment for 5 to 10 minute. For example, when a homo mixer (T.K.HOMO MIXER MARKII Model 2.5, manufactured by PRIMIX Corporation) is used, preferably, the whey protein aggregates can be prepared by simultaneously subjecting a whey protein solution to heat treatment of 75 to 85°C and mechanical shearing
20 treatment at a rotation speed of 100 to 10000 rpm, for 5 to 10 minute.

[0040]

 Further, in the whey protein aggregate, preferably, the whey protein solution is adjusted to pH 5.5 to 7, more preferably
25 pH 6 to 7. That is, the whey protein aggregate is preferably prepared at a neutral pH region.

[0041]

 The whey protein aggregate used in the present invention may be in a liquid form, a liquid or gel form obtained by
30 concentration according to a vacuum evaporation method or a freeze concentration method, and a powder obtained by drying according to a spray drying method or a freeze drying method, and the shape and properties of the whey protein aggregate are not particularly limited. Preferably, however, the whey protein
35 aggregate is not dried (for example, by spray drying or freeze drying) and is in the form of a liquid containing water derived from

the whey protein solution.

[0042]

The whey protein aggregate used in the present invention can be used as an alternative to fat. The expression "alternative to fat" as used herein means substances that function like fat. Functions like fat include the effect of ensuring high overrun to maintain the shape retention of the product, the effect of food feeling or flavor generally conceived in fat, for example, the effect of imparting good food feeling inherent in fat, or the effect of imparting good flavor inherent in fat, that is, the effect of imparting rich feeling that gives an image of fresh cream. The alternative to fat according to the present invention may have a higher level of function than the function of original fat. That is, the alternative to fat according to the present invention may be used, for example, as foaming agents, shape stabilizers, and flavor improvers.

[0043]

Here the overrun means the inclusion of air and is expressed by equation 1: $OR (\%) = \{(\text{volume of air bubble-containing emulsion [ml]} / \text{mass of air bubble-containing emulsion [g]}) - 1\} \times 100$. When the overrun is low, food feeling is so poor that, in particular, in bubble-containing emulsions in which air bubbles are formed while freezing, like ice creams, freezing cannot be carried out stably and evenly. A high overrun means that overrun properties on a level similar to or higher than an air bubble-containing emulsion having an ordinary fat content are exhibited in a given period of time for air bubble formation, particularly in start. For example, in ice creams, the high overrun means that the overrun properties are on a level similar to or larger than conventional ice creams having a fat content of not less than 8.0%, that is, that, when a raw material milk (an ice cream mix) is frozen with stirring in a freezer (for example, -20°C) for ice cream production, OR is not less than 15% 60 minute after the start of freezing and is not less than 20% 120 minute after the start of freezing. The expression "the shape retention of the product is maintained" means that air bubbles of the product can

be stably maintained over a long period of time.

[0044]

In the present invention, the "air bubble-containing emulsion" as used herein is not theoretically limited but means air
5 bubble-containing emulsions including water or oil as a dispersion medium and particles of a whey protein aggregate that surround air bubbles instead of fat-derived fat particles to ensure an overrun state. In technical fields to which the present invention belongs, the air bubble-containing emulsion is sometimes called a
10 foamable oil-in water emulsion or a foamable water-in-oil emulsion.

[0045]

In a preferred embodiment of the present invention, the air bubble-containing emulsion of the present invention is a food.
15 Specifically, examples thereof include ice creams, ice confectioneries, frozen yogurts, whip creams, whip deserts, margarines, spreads, and whip-type soft cheeses. Preferred are ice creams, ice confectioneries, whip creams, and whip deserts.

[0046]

20 In the present invention, the "ice cream" means a product obtained by processing milk or a food produced using milk as a raw material, or providing milk or a material including milk as a main raw material, and freezing the stock solution while forming air bubbles in the stock solution and generally means a product
25 having a milk solid content (a milk component) of not less than 30% by weight. It is a matter of course that products similar to products defined above are also embraced in ice creams. The "ice confectioneries" as used herein mean products other than ice creams, that is, a product that is obtained by providing a sugar
30 solution or a sugar solution with other food mixed therein and freezing the stock solution while forming air bubbles in the stock solution, or by grinding an edible ice, mixing a sugar solution or other food into the ground product, and refreezing the stock solution while forming air bubbles in the stock solution and is
35 applied in the frozen state for edible use. The "frozen yogurt" means products other than ice creams, that is, cold

confectioneries including yogurt as a main raw material.

[0047]

5 The "whip cream" as used herein means a product obtained by whipping a material that contains a milk protein, a part or whole of milk fat replaced with fat and oil (for example, vegetable fat and oil) other than milk fat and has shape, color, and properties similar to those of creams.

[0048]

10 The "whip desert" as used herein means a product obtained by whipping a milk-based desert that contains a milk protein, a part or whole of milk fat replaced with fat and oil (for example, vegetable fat and oil) other than milk fat and is solidified with a gelling agent.

[0049]

15 The "margarine" as used herein is a product that is generally called "margarine" in the market, or a margarine-like food similar to the margarine. The "spread" as used herein is a product called "spread" generally or in the market and a margarine-like food similar to spread. In the present invention, the "whip-type soft cheese" means cheeses having food feeling improved by incorporating air bubbles in soft cheeses, and cheese-like foods.

[0050]

25 The "low-fat or fat-free air bubble-containing emulsion" as used herein means an air bubble-containing emulsion having a fat content that is reduced to a lower value than conventional air bubble-containing emulsions or is infinitesimally lowered to zero (0). In the low-fat or fat-free air bubble-containing emulsion according to the present invention, specifically the fat content (concentration) varies depending upon the type of the air bubble-containing emulsion. For example, for frozen products such as ice creams, ice confectioneries, frozen yogurts, the content of fat in the low-fat air bubble-containing emulsion may be 0.5 to 5% by weight, preferably 0.5 to 3% by weight, more preferably 0.5 to 1.5% by weight, in terms of milk fat-containing fat component based on the air bubble-containing emulsion, and

35

the content of fat in the fat-free air bubble-containing emulsion may be less than 0.5% by weight in terms of milk fat-containing fat component based on the air bubble-containing emulsion. For whip creams, the content of fat in the low-fat air bubble-containing emulsion may be 0.5 to 30% by weight, preferably 0.5 to 20% by weight, more preferably 0.5 to 10% by weight, in terms of milk fat-containing fat component based on the air bubble-containing emulsion, and the content of fat in the fat-free air bubble-containing emulsion may be less than 0.5% by weight in terms of milk fat-containing fat content based on the air bubble-containing emulsion. For whip deserts, the content of fat in the low-fat air bubble-containing emulsion may be 0.5 to 5% by weight, preferably 0.5 to 3% by weight, more preferably 0.5 to 1.5% by weight, in terms of milk fat-containing fat content based on the air bubble-containing emulsion, and the content of fat in the fat-free air bubble-containing emulsion may be less than 0.5% by weight.

[0051]

For margarines, the content of fat in the low-fat air bubble-containing emulsion may be 0.5 to 60% by weight, preferably 0.5 to 40% by weight, more preferably 0.5 to 20% by weight, and the content of fat in the fat-free air bubble-containing emulsion may be less than 0.5% by weight. For spreads, the content of fat in the low-fat air bubble-containing emulsion may be 0.5 to 60% by weight, preferably 0.5 to 40% by weight, more preferably 0.5 to 20% by weight, and the content of fat in the fat-free air bubble-containing emulsion may be less than 0.5% by weight. For whip-type soft cheeses, the content of fat in the low-fat air bubble-containing emulsion may be 0.5 to 20% by weight, preferably 0.5 to 10% by weight, more preferably 0.5 to 5% by weight, and the content of fat in the fat-free air bubble-containing emulsion may be less than 0.5% by weight.

[0052]

The air bubble-containing emulsion according to the present invention may further optionally contain, in addition to the whey protein aggregate, one or at least two materials selected

from milks or other milk products, saccharides, sweetened egg yolks, perfumes, salts (for example, common salts), crystalline celluloses, fats and oils, and dyes.

[0053]

5 Milks or other milk products used in the present invention are not particularly limited as long as the fat content (concentration) of the air bubble-containing emulsion can be regulated to a desired value. Milks or other milk products used in the present invention are preferably, for example, skim milks
10 obtained by defatting a part or whole of the milk fat component, such as defatted concentrated milks, sugar-free condensed skim milks, sweetened condensed skim milks, powdered skimmed milks, low-fat milks, and fat-free milks, more preferably defatted concentrated milks and defatted milk powders, from the
15 viewpoint of reducing the content of fat in the air bubble-containing emulsion. They may be used solely or in a combination of two or more of them.

[0054]

20 Any saccharide commonly used in the field of foods may be used in the present invention without particular limitation, and examples thereof include glucose, fructose, sugar, reducing maltose, granulated sugar, isomerized sugar, high-fructose liquid sugar, glutinous starch syrup, powdery candies, high intensity sweeteners (for example, xylitol, stevia extracts, palatinose,
25 aspartame, acesulfame K, steviae, saccharine, saccharine sodium, or sucralose), sugar alcohol (for example, erythritol, xylitol, sorbitol, maltitol, lactitol, parachinit, or isomaltitol). Saccharides used in the present invention are preferably, for example, sugar, glutinous starch syrup, and powder candies,
30 because good flavor and body feeling can be imparted. One of them may be used solely, alternatively two or more of them may be used in combination.

[0055]

35 The fat and oil used in the present invention is not particularly limited as long as the content (concentration) of fat in the air bubble-containing emulsion can be regulated to a desired

value. The fat and oil used in the present invention is preferably, for example, a vegetable fat and oil, because the content of fat in the air bubble-containing emulsion can be reduced.

[0056]

5 Production process

The low-fat or fat-free air bubble-containing emulsion according to the present invention is obtained by mixing a whey protein aggregate with water, optionally mixing the mixture with one or at least two materials selected from milks or other milk
10 products, saccharides, sweetened egg yolks, perfumes, and dyes, and stirring the mixture to form air bubbles. Thus, according to one aspect of the present invention, there is provided a process for producing a low-fat or fat-free air bubble-containing emulsion, the process comprising: mixing a whey protein aggregate that is
15 prepared by simultaneously subjecting a whey protein concentrate to heat treatment and mechanical shearing treatment and comprises particles having a 50% mean particle diameter of 2 to 10 μm , into water and stirring the mixture to form air bubbles. In the process for producing a low-fat or fat-free air
20 bubble-containing emulsion according to the present invention, the whey protein aggregate may be used as an alternative to fat.

[0057]

The low-fat or fat-free air bubble-containing emulsion produced by the above process is substantially free from
25 stabilizers and emulsifiers. Here the "substantially free from stabilizers and emulsifiers" and "substantially without the need to use stabilizers and emulsifiers" mean that stabilizers and emulsifiers are not added or not contained in such an amount (an effective amount) that exerts respective effects attained by them.

30 [0058]

Water into which a whey protein aggregate used in the present invention is to be mixed is not always necessary when the whey protein aggregate as such contains a satisfactory amount of water as a solution. Alternatively, milks or other milk products
35 having a high water content may be used as a substitute for water. Further, they may be used in combination.

[0059]

The concentration of the whey protein aggregate added in the air bubble-containing emulsion according to the present invention is preferably 0.5 to 10% by weight, more preferably 1 to 5% by weight, in terms of a dry powder.

[0060]

The expression "air bubbles are formed with stirring" as used herein means that shearing force is applied to the mixture of the whey protein concentrate for foaming (whipping). Apparatuses that form air bubbles include, for example, whip mixers, continuous whippers, ice creamers, and freezers for ice cream production typified by batch freezers.

[0061]

The process for producing a low-fat or fat-free air bubble-containing emulsion according to the present invention may if necessary further include treatments applicable in the production of conventional air bubble-containing emulsions, such as mixing, heating, melting, filtration, homogenization, heat sterilization, cooling, freezing, and aging.

[0062]

In a preferred embodiment of the present invention, the process for producing a low-fat or fat-free air bubble-containing emulsion according to the present invention uses, in the production process, the whey protein aggregate as an alternative to fat without drying. The expression "without drying" as used herein means that a whey protein aggregate obtained from the whey protein solution is used without being dried by spray drying or freeze drying, in such a state that water derived from the whey protein solution is contained. The whey protein aggregate containing water obtained by this process can actually provide a low-fat or fat-free air bubble-containing emulsion having better properties than the whey protein aggregate subjected to drying treatment.

[0063]

According to a preferred aspect of the present invention, there is provided a process for producing a low-fat or fat-free ice

cream, ice confectionery, or frozen yogurt, the process comprising: mixing a whey protein aggregate that is prepared by simultaneously subjecting a whey protein concentrate to heat treatment and mechanical shearing treatment and comprises particles having a 50% mean particle diameter of 2 to 10 μm , into water and stirring and freezing the mixture to form air bubbles. In a preferred embodiment of the present invention, the air bubbles are formed at a temperature of -2.5°C or below from the viewpoint of ensuring a desired overrun.

10 [0064]

According to a more preferred aspect of the present invention, there is provided a process for producing a low-fat or fat-free ice cream, the process comprising: mixing a whey protein aggregate into water, subjecting the mixture to heat dissolution and/or dispersion, filtering the solution or dispersion, subjecting the filtrate to homogenization and heat sterilization, subjecting the solution to aging, and stirring and freezing the mixture to form foams.

20 EXAMPLES

[0065]

The present invention is further illustrated by the following Examples. However, the present invention is by no means to be construed as being limited to them. In the Examples, only ice creams are described. However, it is needless to say that application to ice confectioneries, frozen yogurts, whip creams, whip deserts, margarines, spreads, and whip-type soft cheeses belonging to air bubble-containing emulsions to which ice creams as well belong could easily be made by a person having ordinary skill in the art.

30 [0066]

Example 1: Preparation (production) of whey protein aggregates
(1) Studies on conditions for preparation of whey protein aggregates (laboratory scale)

35 Conditions for the preparation of whey protein aggregates were studied.

[0067]

i) Studies on solid content concentration

A whey protein concentrate (142.7 g) obtained by regulating a protein content to 34% by weight and performing spray drying (hereinafter referred to as "WPC34") (solid content concentration: 97% by weight (fat-free milk solid content: 96% by weight, fat content: 1% by weight), obtained from Meiji Co., Ltd.) and 657.3 g of water were placed in a homomixer provided with a heating/stirring dissolution tank (T.K.HOMO MIXER MARKII Model 2.5, manufactured by PRIMIX Corporation), and the contents were stirred and dissolved (dispersed) at 4000 rpm while heating to 55°C for mechanical shearing treatment (solid content concentration: 17.3% by weight (fat-free milk solid content: 17.1% by weight, fat content: 0.2% by weight)). The whey protein solution thus obtained had pH 6.3.

[0068]

After the temperature of the whey protein solution reached 55°C, the whey protein solution was subjected to mechanical shearing treatment by taking advantage of a stirring function of a homo mixer at 4000 rpm while continuing the heating until the temperature reached 75°C. After temperature of the whey protein solution reached 75°C, mechanical shearing treatment was continued at 75°C for 5 minute to heat- agglomerate the whey protein. Thereafter, mechanical shearing treatment was continued at 4000 rpm, and cooling was continued until the temperature reached 40°C to obtain a whey protein aggregate (MP, heat shearing solution) (sample 1).

[0069]

For the whey protein aggregates thus obtained, the aggregation level was confirmed, and the 50% mean particle diameter of particles contained in the aggregates was measured. The 50% mean particle diameter was measured with a particle size distribution meter LS230 (manufactured by Beckman Coulter, Inc.). Specifically, a 50% particle diameter in terms of integrated value was calculated from a graph of the actually obtained particle size distribution. The results are shown in

Table 1.

[0070]

Whey protein aggregates (MP) (samples 2 to 5) were prepared in the same manner as described above, except that the solid content concentration of the whey protein solution was regulated to concentrations as specified in Table 1 by regulating the content of WPC34 (solid content concentration: 97% by weight), and, if necessary, the pH of the whey protein solution was regulated to 6.3 by the addition of a pH adjustor (hydrochloric acid or an aqueous potassium hydroxide solution). For the whey protein aggregates thus obtained, the aggregation level was confirmed, and the 50% mean particle diameter of particles contained in the aggregates was measured. The results are shown in Table 1.

[0071]

[Table 1]

Table 1: Studies on conditions for preparation of whey protein aggregates					
	Sample 2	Sample 3	Sample 1	Sample 4	Sample 5
Solid content (% by weight)	9.0	14.0	17.3	25.0	33.0
Protein (% by weight)	3.1	4.8	6.0	8.5	11.2
Aggregability	Aggregable	Aggregable	Aggregable	Non-aggre gable	Non-aggre gable
50% Mean particle diameter (μm)	6.8	4.2	2.3	0.3	0.0
Applicability to present invention	Suitable	Suitable	Best suitable	Unsuitable	Unsuitable

[0072]

Whey protein aggregates containing particles having a 50% mean particle diameter of not less than 2 μm were evaluated as aggregates suitable for the present invention based on the results of overrun properties in Example 2. The results are shown in Table 1.

[0073]

ii) Studies on pH

Whey protein aggregates were prepared in the same manner as described above (in the same amount and the same method as) in connection with sample 1 in step i) in Example 1 (1), except that the pH of the whey protein solutions was regulated to 4.5, 5.4, 6.0, 6.3, 7.2, or 8.0 by the addition of pH adjustors (hydrochloric acid or aqueous potassium hydroxide solution). As a result, when whey protein solutions having a pH value of 5.4 or less and a pH value of 7.2 or more were used, not only whey protein aggregates but also any other aggregate was hardly obtained (non-aggregated). On the other hand, when whey protein solutions having a pH value of 6.0 and a pH value of 6.3 were used, whey protein aggregates containing particles having a suitable 50% mean particle diameter were obtained.

[0074]

iii) Studies on shearing force (rotation speed)

Whey protein aggregates were prepared in the same manner as described above (in the same amount and the same method as) in connection with sample 1 in step i) in Example 1 (1), except that, when the temperature of the whey protein solution reached 55°C, the rotation speed [rpm] of a homo mixer in mechanical shearing treatment was regulated to 0, 2000, 4000, 8000, or 12000, and, optionally, the pH of the whey protein solutions was regulated to 6.3 by the addition of a pH adjustor (hydrochloric acid or aqueous potassium hydroxide solution). As a result, when the mechanical shearing treatment was carried out at a rotation speed [rpm] of 0 and 12000 with a homomixer, not only whey protein aggregates but also any other aggregate was hardly obtained (non-aggregated). On the other hand, when the

mechanical shearing treatment was carried out at a rotation speed [rpm] of 2000 to 8000 with the homomixer, whey protein aggregates containing particles having a suitable 50% mean particle diameter were obtained. In the homomixer, the rotation speeds [rpm] of 0, 2000, 4000, 8000, and 12000 correspond to shearing forces (shearing stresses) [Pa] of 0, 38, 75, 150, and 220, respectively.

[0075]

A shearing speed [m/sec] was calculated from a rotation speed [rpm] and a stirring blade length by equation 2, and the shearing force (shearing stress) was calculated from the shearing speed, a gap, and a liquid viscosity by equation 3. A schematic diagram of a rotation section in the homomixer is shown in Fig. 1.

[0076]

[Mathematical 1]

Equation 2:

$$u = \pi DN$$

where u: shearing speed, D: stirring blade length, and N: rotation speed.

[0077]

[Mathematical 2]

Equation 3:

$$\tau = \mu \frac{du}{dr} = \mu \frac{u}{\delta}$$

where τ : shearing stress, μ : liquid viscosity, γ : size of gap, and δ : gap.

[0078]

The results on the rotation speed and the shearing stress in the homomixer are shown in Table 2.

[0079]

[Table 2]

Shearing stress of homomixer

Rotation speed [rpm]	Shearing speed [m/sec]	Shearing stress [Pa]
100	0.1	1.9
200	0.3	3.7
250	0.4	4.7

2000	2.9	38
4000	5.8	75
5000	7.2	94
8000	12	150
10000	14	190
12000	17	220

[0080]

(2) Study on conditions for preparation of whey protein aggregate (pilot plant scale)

5 WPC34 (obtained from Meiji Co., Ltd.) (7134.0 g) and 32866.0 g of water were placed in a turbo mixer (manufactured by Scanimax), and the mixture was heated to about 55°C, was stirred and dissolved (dispersed) at 2500 rpm, and was subjected to mechanical shearing treatment. The whey protein solution
10 thus obtained had pH 6.3. The heat treatment and the mechanical shearing treatment were simultaneously continued until the temperature of the whey protein solution reached 75°C. After the temperature of the whey protein solution reached 75°C, the mechanical shearing treatment was continued at 75°C for 5
15 minute to heat- agglomerate the whey protein. Thereafter, the heat treatment was stopped, and the system was cooled while continuing the mechanical shearing treatment at 2500 rpm until the temperature reached 40°C or below. After the temperature reached 40°C, the mechanical shearing treatment was stopped to
20 obtain a whey protein aggregate (MP, heat shearing solution).

[0081]

The 50% mean particle diameter of particles contained in the whey protein aggregate thus obtained was 3 μ m.

[0082]

25 Example 2: Overrun properties of fat-free ice cream

(1) Content (concentration) and overrun properties of whey protein aggregate

Ice creams were produced by an ordinary method according to formulations specified in Tables 3 and 4.
30 Specifically, raw materials were mixed and dissolved (dispersed) at 65 to 70°C to prepare a mixed solution. The mixed solution

was filtered (40-mesh filter, manufactured by Iwai Kikai Kogyo Co., Ltd.), was homogenized at 65 to 70°C (first stage: 100 kg/cm³, second stage: 50 kg/cm³), and was held at 85 to 90°C for 15 to 30 sec for sterilization, followed by cooling to 10°C or below. The sterilized solution (mixed solution) thus obtained was aged at 10°C or below (for example, was held with stirring) and was then subjected to freezing (for example, freezing with stirring) at -3 to -6°C.

[0083]

Here the whey protein aggregate (MP) used was one obtained in Example 1 (2) (50% mean particle diameter: 3 μ m). The whey protein aggregate had a solid content of 17.3% by weight (fat-free milk solid content concentration: 17.1% by weight, fat content: 0.2% by weight) and a protein content of 6.0% by weight. A defatted concentrated milk (obtained from Meiji Co., Ltd.) (fat-free milk solid content: 33% by weight, protein: 11.6% by weight) was mixed (added) so that the content of the whole protein was identical for each Example.

[0084]

[Table 3]

Table 3: Studies on conditions for preparation of fat-free air bubble-containing emulsions (1)
(Influence of presence or absence of whey protein aggregate)

		Test Example 1	Comparative Example 2
Raw materials		Whey protein aggregate 30% by weight	Defatted concentrated milk 30% by weight
Protein	Whey protein aggregate	30.0	0
	Defatted concentrated milk	14.6	30.0
Saccharides	Glutinous starch syrup	15.3	15.3
	Powdered candy	6.0	6.0
	Sugar	7.9	7.9
Egg yolk	Sweetened (20%) egg	1.5	1.5

	yolk		
Dye	Annatto dye	0.02	0.02
Water		24.68	39.28

Unit: mixing ratio (% by weight)

[0085]

[Table 4]Table 4: Studies on conditions for preparation of fat-free air bubble-containing emulsions (2)

(Influence of concentration of whey protein aggregate)

		Test Example 2	Test Example 3	Test Example 1	Comparative Example 1
Raw materials		Whey protein aggregate 10% by weight	Whey protein aggregate 20% by weight	Whey protein aggregate 30% by weight	Defatted concentrated milk 20% by weight
Protein	Whey protein aggregate	10.0	20.0	30.0	0
	Defatted concentrated milk	24.9	19.7	14.6	30.0
Saccharides	Glutinous starch syrup	15.3	15.3	15.3	15.3
	Powdered candy	6.0	6.0	6.0	6.0
	Sugar	7.9	7.9	7.9	7.9
Egg yolk	Sweetened (20%) egg yolk	1.5	1.5	1.5	1.5
Dye	Annatto dye	0.02	0.02	0.02	0.02
Water		34.38	29.58	24.68	39.28

5

Unit: mixing ratio (% by weight)

[0086]

For the ice creams thus obtained, the overrun (OR) properties were evaluated. Here the overrun (OR) was

10

calculated by using as an index an increasing rate of the volume of ice cream at a time elapsed from freezing on the assumption that the volume of a raw milk (ice cream mix) before freezing with a batch freezer (for example, manufactured by Daito Food Machinery Co., Ltd.) was 0%. The results are shown in Figs. 2 and 3.

[0087]

As shown in Fig. 2, in Test Example 1, the overrun properties were more proper and better than those in Comparative Example 1, demonstrating that, despite freedom from fat, food feeling comparable to that of conventional ice creams could be realized. Further, as shown in Fig. 3, it was demonstrated that the overrun properties depend upon the concentration of the whey protein aggregate.

[0088]

(2) Types and overrun properties of whey proteins

Ice creams were produced by the method described in Example 2 (1) according to formulations specified in Table 5. The whey protein aggregate obtained in Example 1 (2) was used as the whey protein aggregate. WPC34 (untreated WPC34, protein: 34% by weight) before the heat treatment and mechanical shearing treatment used in Example 1 was used as the whey protein concentrate. Further, Simplesse 100 was a commercially available product (obtained from Saneigen F.F.I Co., Ltd.) (protein: 5.9% by weight).

[0089]

[Table 5]

Table 5: Studies on conditions for preparation of fat-free air bubble-containing emulsions (3)
(Influence of type of whey protein)

		Test Example 1	Comparative Example 2	Comparative Example 3	Comparative Example 1
Raw material		Whey protein aggregate 30% by weight	Whey protein concentrate 30% by weight	Simplese 100 30% by weight	Defatted concentrated milk 30% by weight
Protein	Whey protein (type)	Whey protein aggregate	Whey protein concentrate	Simplese 100	0
		30.0	30.0	30.0	
	Defatted concentrated milk	14.6	14.6	14.6	30.0
Saccharides	Glutinous starch syrup	15.3	15.3	15.3	15.3
	Powdered candy	6.0	6.0	6.0	6.0
	Sugar	7.9	7.9	7.9	7.9
Egg yolk	Sweetened (20%) egg yolk	1.5	1.5	1.5	1.5
Dye	Annatto dye	0.02	0.02	0.02	0.02
Water		24.68	24.68	24.68	39.28

Unit: mixing ratio (% by weight)

[0090]

For the ice creams thus obtained, the overrun (OR) properties were evaluated according to the method described in Example 2 (1). The results are shown in Fig. 4.

5 [0091]

As shown in Fig. 4, in Test Example 1 where the whey protein aggregate was used, the overrun properties were suitable and best. The overrun properties of Comparative Example 3 where the commercially available product (Simplesse 100) were next best, and the overrun properties of Comparative Example 1 where the whey protein aggregate was not used were third. Thus, the overrun properties of the whey protein aggregate according to the present invention were more suitable and better than those of the commercially available product (Simplesse 100).

[0092]

(3) Concentration and overrun properties of fat-free milk solid(SNF)

Ice creams were produced by the method described in Example 2 (1) according to formulations specified in Table 6. Here the whey protein aggregate obtained in Example 1 (2) was used as the whey protein aggregate. Further, a defatted concentrated milk (protein: 11.6% by weight) was used as a supply source for the fat-free milk solid.

25 [0093]

[Table 6]

Table 6: Studies on conditions for preparation of fat-free air bubble-containing emulsions (4)

(Influence of concentration of fat-free milk solid)

	Test Example 4	Test Example 1	Test Example 5
Raw material	Fat-free solid 5% by weight (whey protein aggregate 30% by weight)	Fat-free solid 10% by weight (whey protein aggregate)	Fat-free solid 13% by weight (whey protein aggregate)

			30% by weight)	30% by weight)
Protein	Whey protein aggregate	30.0	30.0	30.0
	Defatted concentrated milk	0	14.6	24.9
Saccharides	Glutinous starch syrup	15.3	15.3	15.3
	Powdered candy	6.0	6.0	6.0
	Sugar	7.9	7.9	7.9
Egg yolk	Sweetened (20%) egg yolk	1.5	1.5	1.5
Dye	Annatto dye	0.02	0.02	0.02
Water		39.28	24.68	14.38

Unit: mixing ratio (% by weight)

[0094]

- 5 For the ice creams thus obtained, the overrun (OR) properties were evaluated by the method described in Example 2 (1). The results are shown in Fig. 5.

[0095]

- 10 As shown in Fig. 5, it was demonstrated that the overrun properties depend upon the concentration of the fat-free milk solid. It was also demonstrated that, when the fat-free milk content of the ice cream is not less than 5% by weight, food feeling comparable to that of conventional ice creams could be realized by mixing (adding) the whey protein aggregate.

15 [0096]

(4) pH and overrun properties of raw material milk (ice cream mix)

- 20 Raw materials were mixed and blended according to formulations specified in Table 7, and the raw material milks (mixed solution, blended solution, and ice cream mix) were

regulated to pH 4, 5, and 6 by the addition of citric acid. Ice creams were produced using the raw material milks having pH values of 4, 5, and 6 by the method described in Example 2 (1). The whey protein aggregate obtained in Example 1 (2) was used

5 as the whey protein aggregate.

[0097]

[Table 7]

Table 7: Studies on conditions for preparation of fat-free air bubble-containing emulsions (5)

10 (Influence of pH of raw material milk (ice cream))

		Test Example 6	Test Example 7	Test Example 8
Raw material		Whey protein aggregate 30% by weight	Whey protein aggregate 30% by weight	Whey protein aggregate 30% by weight
Protein	Whey protein aggregate	30.0	30.0	30.0
	Defatted concentrated milk	14.6	14.6	14.6
Saccharides	Glutinous starch syrup	15.3	15.3	15.3
	Powdered candy	6.0	6.0	6.0
	Sugar	7.9	7.9	7.9
Egg yolk	Sweetened (20%) egg yolk	1.5	1.5	1.5
Dye	Annatto dye	0.02	0.02	0.02
Water		24.68	24.68	24.68
pH		4	5	6

Unit: mixing ratio (% by weight)

[0098]

For the ice creams thus obtained, the overrun (OR) properties were evaluated by the method described in Example 2 (1). The results are shown in Fig. 6.

5 [0099]

As shown in Fig. 6, it was demonstrated that, when the pH value of the raw material milk (ice cream mix) was 4 or more, the mixing (addition) of the whey protein aggregate did not affect the overrun properties.

10 [0100]

(5) Mean particle diameter and overrun properties of whey protein aggregates

Ice creams were produced by the method described in Example 2 (1) according to formulations specified in Table 8. The whey protein aggregate (50% mean particle diameter: 3 μm) was a whey protein aggregate obtained in Example 1 (2). The whey protein aggregate (50% mean particle diameter: 5 μm) was a whey protein aggregate prepared in the same manner as in Example 1 (2), except that the holding time of the heat treatment and mechanical shearing treatment at 75°C after the temperature reached 75°C was increased from 5 minute to 10 minute and, further, the rotation speed of the mechanical shearing treatment was changed from 2500 rpm to 4000 rpm.

[0101]

25 [Table 8]

Table 8: Studies on conditions for preparation of fat-free air bubble-containing emulsions (6)

(Influence of mean particle diameter of fat-free air bubble-containing emulsions)

	Test Example 1	Test Example 9	Comparative Example 1
Raw material	Whey protein aggregate 30% by weight (mean particle diameter: 3	Whey protein aggregate 30% by weight (mean particle	Fat-free concentrated milk 30% by weight

		$\mu\text{m})$	diameter: 3 $\mu\text{m})$	
Protein	Whey protein aggregate	30.0	30.0	0
	Defatted concentrated milk	14.6	14.6	30.0
Saccharides	Glutinous starch syrup	15.3	15.3	15.3
	Powdered candy	6.0	6.0	6.0
	Sugar	7.9	7.9	7.9
Egg yolk	Sweetened (20%) egg yolk	1.5	1.5	1.5
Dye	Annatto dye	0.02	0.02	0.02
Water		24.68	24.68	39.28

Unit: mixing ratio (% by weight)

[0102]

- 5 For the ice creams thus obtained, the overrun (OR) properties were evaluated by the method described in Example 2 (1).

[0103]

- 10 It was demonstrated that, in Test Example 1 and Test Example 9, the overrun properties were more suitable and better than those in Comparative Example 1 and, despite the freedom from fat, food feeling comparable to conventional ice creams could be realized.

[0104]

- 15 Example 3: Overrun properties of low-fat ice creams

- 20 Low-fat ice creams were produced by the method described in Example 2 (1) according to formulations specified in Table 9. Here the whey protein aggregate used was one obtained in Example 1 (2). WPC34 (untreated WPC34, protein: 34% by weight) before the heat treatment and mechanical shearing

treatment used in Example 1 was used as the whey protein concentrate. Further, a vegetable fat and oil was used as the fat ingredient.

[0105]

5 [Table 9]

Table 9: Studies on conditions for preparation of low-fat air bubble-containing emulsions (1)
(Influence of concentration of whey protein aggregates)

		Test Example 10	Test Example 11	Test Example 12	Comparative Example 4
Raw material		Whey protein aggregate 10% by weight	Whey protein aggregate 20% by weight	Whey protein aggregate 30% by weight	Defatted concentrated milk 30% by weight
Protein	Whey protein aggregate	10.0	20.0	30.0	0
	Defatted concentrated milk	14.6	14.6	14.6	30.0
Fat and oil	Vegetable fat and oil	3.0	3.0	3.0	3.0
Saccharides	Glutinous starch syrup	15.3	15.3	15.3	15.3
	Powdered candy	6.0	6.0	6.0	6.0
	Sugar	7.9	7.9	7.9	7.9
Egg yolk	Sweetened (20%) egg yolk	1.5	1.5	1.5	1.5
Dye	Annatto dye	0.02	0.02	0.02	0.02
Water	Water	41.68	31.68	21.68	36.28

Unit: mixing ratio (% by weight)

[0106]

10 For the ice creams thus obtained, the overrun (OR) properties were evaluated by the method described in Example 2

(1). The results are shown in Fig. 7.

[0107]

As shown in Fig. 7, it was demonstrated that the overrun properties depend upon the concentration of the whey protein aggregates.

[0108]

Example 4: Overrun stability of low-fat or fat-free ice creams

(1) Overrun stability of low-fat or fat-free ice creams (overrun: 70%)

Ice creams were produced in the same manner as in Example 2 (1), except that formulations were as described in Test Examples 1 to 3 in Example 2 (that is, (MP-containing) fat-free ice creams with 30, 10, and 20% by weight of whey protein aggregates (MP) incorporated therein), Comparative Example 1 (that is, (MP-free) fat-free ice cream with MP not incorporated therein), Test Examples 10 to 12 (that is, low-fat ice creams with 10, 20, and 30% by weight of MP incorporated therein), and Comparative Example 4 (low-fat ice cream with MP not incorporated therein). In freezing, the overrun of the ice creams was set to 70%, and these ice creams were filled into paper cups, followed by freezing at -30°C or below.

[0109]

For the ice creams thus obtained, the overrun stability was evaluated. In the evaluation of the overrun stability, the ice cream filled into the paper cup was regulated to -18°C, the paper cup was peeled off, the cream was allowed to stand at room temperature (about 25°C), and the state of dissolution was visually observed. Specifically, the overrun stability of the ice creams thus obtained was evaluated in terms of the state of the ice creams three hr after the start of standing.

[0110]

As a result, as shown in Fig. 8, in Test Example 1 (fat-free ice cream with 30% by weight of MP incorporated therein), visual observation suggested that air bubbles (overrun state) were stably held and the ice cream had smooth properties. On the other hand, in Comparative Example 1 (fat-free ice cream with MP

not incorporated therein), as a result of visual observation, large air bubbles appeared on the surface of the ice cream as the ice cream dissolved, suggesting that the air bubbles were unstable. In Test Example 12 (low-fat ice cream with 30% by weight of MP incorporated therein), visual observation suggested that air bubbles were stably held and the ice cream had smooth properties. On the other hand, in Comparative Example 4 (low-fat ice cream with MP not incorporated therein), as a result of visual observation, large air bubbles appeared on the surface of the ice cream as the ice cream dissolved, suggesting that the air bubbles were unstable. That is, in the ice creams with MP incorporated therein, in any of fat-free and low-fat ice creams, air bubbles were stably held and the ice creams had smooth properties.

[0111]

15 (2) Overrun stability of fat-free ice creams (overrun: 60%)

Ice creams were produced in the same manner as in Example 4 (1) according to formulations as described in Test Examples 1 to 3 (that is, (MP-containing) fat-free ice creams with 30, 10, and 20% by weight of whey protein aggregates (MP) incorporated therein) and Comparative Example 1 (that is, (MP-free) fat-free ice cream with MP not incorporated therein), except that, in freezing, overrun of ice creams was brought to 60%. For the ice creams thus obtained, the overrun stability was evaluated.

25 [0112]

As a result, in Test Example 1 (fat-free ice cream with 30% by weight of MP incorporated therein), the air bubbles (overrun state) were stably held, and the ice cream had smooth properties. In Test Example 2 (fat-free ice cream with 10% by weight of MP incorporated therein), Test Example 3 (fat-free ice cream with 20% by weight of MP incorporated therein), and Comparative Example 1 (fat-free ice cream with MP not incorporated therein), air bubbles were unstable. Accordingly, in fat-free ice creams with not less than 30% by weight of MP incorporated therein, it was demonstrated that the overrun stability was improved and the ice creams had suitable and good properties.

[0113]

Example 5: Sensory evaluation test of ice creams(1) Sensory evaluation test of low-fat ice creamsi) Sensory evaluation test

- 5 Ice creams were produced by the method described in Example 2 (1) according to formulations specified in Table 10. Here the whey protein aggregate used was one obtained in Example 1 (2). The fat content in Test Example 13 was 1% by weight, and the fat content in Comparative Example 5 was 10% by weight. In Comparative Example 5, an ice cream was prepared so that the solid mixing ratio was equal to that in Test Example 13.

[0114]

[Table 10]

Table 10: Studies on conditions for preparation of low-fat air bubble-containing emulsions (2)

(Influence of presence or absence of whey protein aggregates)

		Test Example 13	Comparative Example 5
Raw material		Fat ingredient with MP incorporated therein 1% by weight	Fat ingredient with MP not incorporated therein 10% by weight
Protein	Whey protein aggregate	30.0	0
	Defatted concentrated milk	14.6	30.0
Lipid	Vegetable fat and oil	2.5	10.0
Saccharides	Glutinous starch syrup	15.3	15.3
	Powdered candy	6.0	6.0
	Sugar	7.9	7.9
Egg yolk	Sweetened (20%) egg yolk	1.5	1.5
Dye	Annatto dye	0.02	0.02

Water	Water	22.48	36.78
-------	-------	-------	-------

Unit: mixing ratio (% by weight)

[0115]

- 5 For the ice creams thus obtained, a sensory evaluation test was carried out. In the sensory evaluation test, the ice creams were evaluated for "creamy feeling" by five skilled panelists.

[0116]

- 10 As a result, all the five skill panelists evaluated the ice cream in Test Example 13 (low-fat ice cream with MP incorporated therein, the fat content being 1% by weight) as having creamy feeling equivalent to that of the ice cream in Comparative Example 5 (conventional ice cream having a fat content of 10% by weight).

15 [0117]

ii) Mutability test

- Ice creams were produced by the method described in Example 2 (1) according to formulations specified in Table 10. The whey protein aggregate used was one obtained in Example 1
- 20 (2).

[0118]

- For the ice creams thus obtained, the meltability was evaluated. In the evaluation of the meltability, the ice cream filled into a paper cup was regulated to -18°C, and the paper cup
- 25 was peeled off, and the ice cream was allowed to stand at room temperature (about 25°C). The state of being melted was visually observed.

[0119]

- As a result, it was demonstrated that the metability of the
- 30 ice cream in Test Example 13 (low-fat ice cream with MP incorporated therein, the fat content being 1% by weight) was equal to that of the ice cream in Comparative Example 5 (conventional ice cream with MP not incorporated, the fat content being 10% by weight).

[0120]

(2) Sensory evaluation test of fat-free ice creams

A sensory evaluation test was carried out for Test Example 1 obtained in Example 2 (1) and Comparative Example 1 (for comparison purposes) obtained in Example 2 (1). In the sensory evaluation test, the ice creams were evaluated for "creamy feeling" by five skilled panelists.

[0121]

As a result, , all the five skilled panelists evaluated the ice cream in Test Example 1 (fat-free ice cream with MP incorporated therein) as having an improved creamy feeling over the ice cream in Comparative Example 1 (fat-free ice cream with MP not incorporated).

[0122]

Example 6: Comparison test for heat resistance of raw material milk (ice cream mix)

The heat resistance of raw material milk was evaluated by mixing and blending raw materials according to formulations specified in Table 11, filling the resultant raw material milk (mixed solution, blended solution, ice cream mix) into a small bottle (capacity: about 20 ml), holding the raw material milk in an oil bath to 90°C with heating and shaking, and visually observing a time necessary for causing aggregates including whey protein aggregates. The whey protein aggregate used was one obtained in Example 1 (2). The whey protein concentrate used was WPC34 (untreated WPC34, protein: 34% by weight) that was used in Example 1 and was at a stage before heat treatment and mechanical shearing treatment. The results are shown in Fig. 9.

[0123]

[Table 11]

Table 11: Comparison test on heat resistance of raw material milk (ice cream mix)

	Test Example 1	Comparative Example 2
Raw material	Whey protein aggregate 30% by weight	Whey protein aggregate 30% by weight

Protein	Whey protein aggregate	30.0	0
	Whey protein concentrate	0	30.0
	Defatted concentrated milk	14.6	14.6
Saccharides	Glutinous starch syrup	15.3	15.3
	Powdered candy	6.0	6.0
	Sugar	7.9	7.9
Egg yolk	Sweetened (20%) egg yolk	1.5	1.5
Dye	Annatto dye	0.02	0.02
Water	Water	24.68	24.68

Unit: mixing ratio (% by weight)

[0124]

- 5 As shown in Fig. 9, as compared with Comparative Example 2, in Test Example 1, the heat resistance was better, and the possibility (risk) of thickening in heat (sterilization) treatment and burning, for example, to a heat exchanger (a sterilizing machine) was lower, demonstrating that the raw material milk
10 could be suitably subjected to continuous heat (sterilization) treatment.

[0125]

- The heat resistance of Test Example 1 and Comparative Example 2 was evaluated in the same manner as described above,
15 except that the raw material milk (ice cream mix) was regulated to pH 7. For Test Example 1 and Comparative Example 2, the results were similar to those in Fig. 9.

[0126]

- The heat resistance of Test Example 1 and Comparative
20 Example 2 was evaluated in the same manner as described above, except that the raw material milk (ice cream mix) was regulated

to pH 6 or less. As a result, the heat resistance was poor for both Test Example 1 and Comparative Example 2.

CLAIMS

- [1] A low-fat or fat-free air bubble-containing emulsion comprising a whey protein aggregate as an alternative to fat,
wherein the whey protein aggregate is produced by simultaneously subjecting a whey protein solution to heat treatment and mechanical shearing treatment, and
wherein the whey protein aggregate contains particles having a 50% mean particle diameter of 2 to 10 μm .
- [2] The low-fat or fat-free air bubble-containing emulsion according to claim 1, wherein the heat treatment is carried out at 75 to 85°C for 5 to 10 minute.
- [3] The air bubble-containing emulsion according to claim 1 or 2, wherein the whey protein solution has a solid content concentration of 5 to 20% by weight.
- [4] The air bubble-containing emulsion according to any one of claims 1 to 3, which is a food.
- [5] The air bubble-containing emulsion according to claim 4, wherein the food is one selected from the group consisting of ice creams, ice confectoineries, frozen yogurts, whip creams, margarines, spreads, and whip-type soft cheeses.
- [6] A process for producing a low-fat or fat-free air bubble-containing emulsion, the process comprising:
mixing a whey protein aggregate that is produced by simultaneously subjecting a whey protein solution to heat treatment and mechanical shearing treatment and contains particles having a 50% mean particle diameter of 2 to 10 μm , into water and
stirring the mixture to form air bubbles.
- [7] A process for producing a low-fat or fat-free ice cream, ice

confectionery, or frozen yogurt, the process comprising:

mixing a whey protein aggregate that is produced by simultaneously subjecting a whey protein solution to heat treatment and mechanical shearing treatment and contains particles having a 50% mean particle diameter of 2 to 10 μm , into water and

stirring and freezing the mixture to form air bubbles.

[8] The process according to claim 7, wherein the air bubbles are formed at a temperature of -2.5°C or below.

[9] The process according to any one of claims 6 to 8, wherein the whey protein aggregate is used as an alternative to fat without drying.