USE OF NATURAL COLOURS IN THE ICE CREAM INDUSTRY

Dr. Juan Mario Sanz Penella
Dr. Emanuele Pedrazzini
Dr. José García Reverter
SECNA NATURAL INGREDIENTS GROUP

Definition of ice cream

Ice cream is a frozen dessert, a term that includes different types of product that are consumed frozen and that includes sorbets, frozen yogurts, non-dairy frozen desserts and, of course, ice cream. In order to simplify its classification, we can consider for practical purposes two different types of frozen desserts: ice cream and sorbets. Ice cream includes all products that have a neutral pH and contain dairy ingredients. While sorbet refers to products with an acidic pH, made with water and other ingredients such as fruit, but without the use of dairy.

Figure 1. Artisanal ice creams based on natural ingredients

Additionally, when referring to ice cream, we are not referring to a single type of product, we are actually referring to a wide range of these. Ice cream is a food in which the three states of matter coexist, namely: water in liquid form and as ice crystals, sugars, fats and proteins in solid form and occluded air bubbles in gaseous form, which give it its special texture.

It should be noted that ice cream is a very complete food from a nutritional point of view since it incorporates in its formulation a wide range of ingredients (sugars, milk, fruits, egg products ...) essential for a balanced diet.

Another aspect of great relevance in the manufacture of ice cream is the hedonic factor. Ice cream is consumed mainly for the pure pleasure of tasting it, the hedonic component being the main factor that triggers its consumption, considering its formulation and design a series of strategies to evoke a full range of sensations: gustatory, olfactory, visual and even, of the touch and the ear. For all these reasons, ice cream is a nutritionally complete product, easy to digest and highly recommended for people with little appetite.

The history of ice cream is very old, with evidence of its existence in ancient civilizations such as Mesopotamian and Roman, among others. Hundreds of years ago, the only source of ice was snow from mountain peaks and glaciers, which was used to cool down sugary drinks, desserts, and fruit preparations for kings' banquets. It was much later, in the 16th century, when the concept of ice cream itself first appeared, disputed the merit of its invention by the French and Italians. Although, the origin of the ice cream industry as it is known today arises from the end of the 19th century and the first half of the 20th century with the development of industrial cold technology. And it is after the Second World War when the consumption of ice cream became widespread, with continuous developments and technological improvements.

The ingredients

The main ingredients for making ice cream are sugar (between 12-15%), dairy (between 20% fat and protein) and water (more than 60%). Some of these ingredients are very common, such as milk and cream, however, others are specific, such as flavors, colors, and sugars with specific technological functionalities.

In addition to the classic ingredients, many others can be added to ice cream to develop particular flavors, colors and textures. Thus, for example, proteins have a stabilizing effect on the emulsion due to its surface tension, while milk fat is essential to develop a correct sensation in the mouth of ice cream. Both affect the texture of the product.

Let us see in a little more detail the different ingredients.

Figure 2. Beet sucrose

Sugars: different carbohydrates are used to make ice creams, each with a different sweetening power and that affect the freezing temperature of the emulsions differently. Namely: sucrose, fructose, dextrose, glucose syrup, maltodextrin and inverted sugar. Sucrose is a disaccharide with high sweetening power and is by far the most widely used. Dextrose (D-glucose) is a monosaccharide that is obtained by enzymatic hydrolysis of corn and has good solubility in cold water. Its sweetening power is less than sucrose, but it acts as an antifreeze, reducing the solidification temperature in aqueous solutions. Glucose syrup is a mixture of dextrose, maltose, trisaccharides, and oligosaccharides. For making ice cream, a glucose syrup with a DE of 40-44 should be used. Among the sugars commonly used, fructose is also used. Fructose is a monosaccharide with a very high sweetening power and high antifreeze capacity.

Dairy: Milk normally of animal origin, but in some cases also vegetable milk, is one of the most important ingredients in the manufacture of ice cream. Whole cow's milk is mostly used, but the use of skimmed milk and skimmed milk powder is also possible. Regarding the latter option, it should be noted that skim milk powder has a high protein content that helps the incorporation of air into ice cream since it favors the development of a frothy structure. That is why it is used as a highly structural ingredient. Milk cream with 30-40% fat is also used. The cream is obtained by skimming the milk and represents the main source of fat in ice cream. It is normally used for its flavor and creaminess.

Figure 3. Milk and other dairy priority components

Figure 4. Egg products as a functional, nutritional and flavor contribution

Egg products: There are different egg products that are commonly used in making ice cream. Historically, the yolk of the egg has been used, while the white has been discarded due to its high water content. The yolk, however, also contains proteins, fats, and specifically lecithin, an emulsifier that served to increase the texture of the ice cream. Pasteurized yolks or frozen yolks are currently used for comfort, efficacy and microbiological safety.

Fruit: In different formats it is commonly used in the manufacture of many different types of ice cream. The use of natural fruit requires a whole series of processing operations as peeling, elimination of seeds and lignocellulosic remains, grinding, sieving, pasteurization, etc. Furthermore, its availability is limited. A much more practical alternative is to use frozen fruit pulp that is ready for use and available all year round.

Figure 5. Fruits as the main ingredient in artisan ice creams

Flavoring products: In order to give ice cream a specific flavor, numerous substances can be used. Thus, for example, one of the most common is the flavor of chocolate or cocoa, using chocolate or cocoa or a combination of both in its preparation. A very common way to apply flavorings is through the use of specific semi-preparations or ice cream pastes. These ice cream pastes are very diverse in flavor (fatty nut pastes, sugar and fruit pastes and mixed pastes) and easy to use, with a presence in the product of approximately 10% by weight.

Figure 6. Cacao

Stabilizer: The stabilizer has the function of increasing and maintaining the creaminess and texture of the ice cream over time. The stabilizer is made up of two components: thickener and emulsifier. The thickener absorbs free water and increases the viscosity of the ice cream, while the emulsifier prevents the separation of fat from the water. It is normally applied in doses of just a few grams per kilogram of ice cream.

Water: Finally, we must consider the presence of water as one of the most important ingredients in ice cream. Water is incorporated through many of the ingredients mentioned above. For example, whole milk has almost 90% water and fresh fruit more than 70%. Water, we must remember that it is the only ingredient that is frozen in ice cream, and the size and arrangement of the microcrystals of ice are essential in the development of the texture of the product.

The process of making ice cream. Main stages.

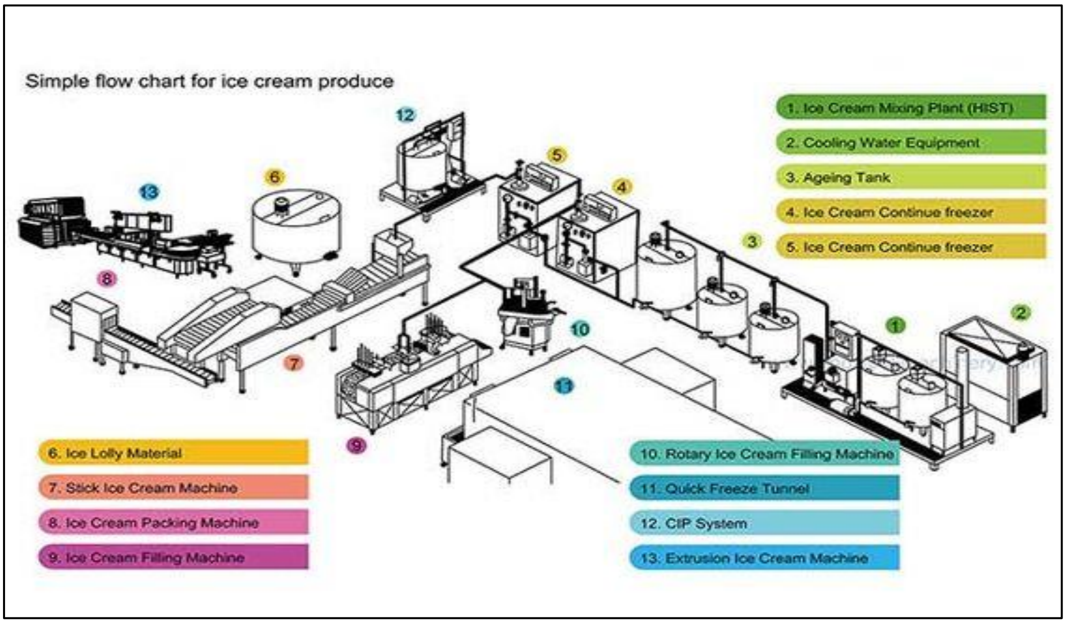

Figure 7. Ice cream processing plant. Courtesy of Snowball Machinery https://snowballmachinery.en.alibaba.com/product/60373856726-802470783/Industrial_Ice_cream_stick_production_line.html

The most common way of making ice cream requires one or more mixtures that are used as the basis from which to develop the full range of flavors and products. Generally, the industrial production process of ice cream can be divided into the following stages: 1. Selection of ingredients, 2. Formulation of recipes, 3. Mixing, 4. Homogenization, 5. Pasteurization, 4. Ripening, 5. Adding flavorings. and aromas, 6. Freezing and 7. Hardening. Not counting other subsequent tasks such as storage, shipping and marketing.

Selection of ingredients: As it happens in the elaboration of any food, a good final product is the result of a good selection of ingredients, reason why in the elaboration of ice creams fresh and first quality products must be used, proceeding with an elaborate plan of quality control of these raw materials.

Recipe formulation: Depending on the seasonal production plan and the market demand, the selected recipes determine the necessary previous operations. Considering the type of ingredients required, the previous tasks of preparing the neutral paste, flavors and colors, will be very different in each case.

Mixing: Since some of the pigments, and especially those of natural origin, are sensitive to heat, they are usually added after homogenization and pasteurization. This practice is also recommended since negative interactions can occur during mixing with other ingredients.

Homogenization: After preheating, the mixture is homogenized at a temperature above 70 ° C by pumping it through a small valve at high pressure. With this shear effect, it is possible to reduce the size of the fat drops to less than one micron and improve the texture of the product. It should be borne in mind that the size of the fat drops has a direct effect on the rheological properties of the ice cream,

Figure 8. MIX-WORKING HTST plant with mixing and preheating tanks, pumps, pasteurization plate exchanger, control panel and homogenizer. Courtesy of Technogel. http://www.technogel.com/data/documents/catalogo-industriale-generale-6.pdf

since, along with the protein structures, a large surface area of the lipids helps to stabilize the air trapped in the ice cream. On the other hand, emulsifiers stabilize oil droplets in the aqueous phase, thus preventing their coalescence during homogenization and pasteurization.

Figure 9. Maturation tanks. Courtesy of Technogel.http://www.technogel.com/data/documents/catalogo-industriale-generale-6.pdf

Pasteurization: To guarantee the microbiological safety of the ice cream, the mixture needs to be pasteurized, but temperatures close to or below 80 ° C are used to avoid protein denaturation, long enough to achieve product stability. Thus, for example, sometimes treatments can be applied at only 70ºC if the time applied is at least 30 minutes, or more severe treatments, for example at 85ºC, with times of only 25 seconds.

Maturation: After pasteurization, the mixture is pumped into the maturation tanks (although in some artisan workshops it is carried out in the same pasteurizer) and is kept between 0 and 4 ° C for 6-12 hours with slight agitation. A correct maturation is essential to obtain high-quality ice creams, since during this stage the necessary time is available for a series of physicochemical phenomena of great technological importance to develop that ensure stabilization of the occluded air. On the one hand, the emulsifiers are adsorbed on the fat globules and the fat crystallizes inside them. During maturation, in addition, the proteins hydrate, reducing the free water available in the medium, facilitating the generation of small ice crystals. These changes are responsible for a creamy and smooth structure of the final product. Finally, the presence of stabilizers and emulsifiers ensures the stability of water-fat emulsions and the subsequent incorporation of aromas and flavors.

Adding flavors and aromas: After the maturation stage is complete, the ice cream mass is ready for the addition of the flavors and aromas. This addition must be carried out followed by a stirring and mixing process that ensures the homogeneous dispersion of the ingredients. If necessary, after this addition, the recipe must be readjusted with the corresponding addition of sugars and cream.

Figure 10. Ice cream freezer. Courtesy of Technogel. http://www.technogel.com/data/documents/catalogo-industriale-generale-1.pdf

Freezing: It is the key stage of the ice cream manufacturing process and a critical phase from the point of view of the microbiological safety of ice cream. Cooling should be carried out as quickly as possible, until reaching at least 5 ° C, which reduces the "critical period" in which most of the pathogens can grow. In addition, during freezing, the liquid mixture solidifies and, while stirring during cooling, air bubbles are retained between the thin ice crystals that grow rapidly, giving rise to the structure of the ice cream. In the most industrialized processes, the mixture is placed in a freezer of the scraped surface heat exchanger type. Inside, there are three actions simultaneously mixing, aerating and freezing the mass, giving rise to a foam that grows in volume as ice crystals are formed, trapping the air bubbles inside. The total increase in the volume of the ice cream is called "overrun" and can be up to 130%.

Hardening: The objective of hardening is to freeze the residual water very quickly so that the ice crystals do not grow and do not affect the creamy texture of the ice cream. This operation must be carried out quickly, less than 20 minutes, which is why it is usually carried out in high-speed freezers at -40 ° C. Once the hardening is finished, the manufacturing process itself has ended.

As it is not the main object of this article, other operations such as packaging, storage, shipping and marketing have been excluded, although it is important to note that they can also have a great impact on product quality, color stability and in the appearance of ice cream.

Natural colours the ice cream industry

In the European Union, the use of food colors is governed by Regulation (EC) No 1333/2008. According to this regulation, certain colours of natural origin can be used without restrictions in the manufacture of ice cream (this is the case of caramel colours E150 a, b, c and d), but others have a limited dosage <150 ppm and others have lower limits, such as this is the case of lycopene (E160d) <40 ppm, annatto, bixin and norbixin (E160b) <20 ppm). In addition, since 2014 the use of aluminum to produce carmine lacquers (E120) is prohibited in the coloring of ice cream. This has prompted the search for valid technological alternatives on the red spectrum. Let us see below some of the most common natural dyes applied to making ice cream.

Figure 11. Lemon ice cream

Yellows: The yellow color is one of the most demanded by the consumer, since there are many flavors related to it (banana, vanilla, lemon, etc.). One of the most common alternatives for coloring ice cream yellow is the use of beta carotenes.

Different beta-carotenes can provide very different shades, from pale yellow to almost orange. Ultimately the tone of beta-carotene will depend on the type of beta-carotene, its formulation, the particle size in the dispersions and its dose. On the other hand, and unlike anthocyanins, beta-carotenes are soluble in oil and insoluble in water, so it is necessary to generate emulsions or encapsulate them to disperse them in ice cream. An advantage of beta-carotenes is their relative heat stability, although they do require some protection against oxidation. Apart from the extracts rich in beta-carotene, there is the interesting possibility of using carrot concentrates with high staining capacity, which allows the production of "clean label" products.

Another alternative to the yellow color is curcumin. Curcumin provides an intense lemon-yellow color, is stable to heat, but has some instability in light. Safflower is also used in making yellow ice cream, although it has a greenish hue and affects the flavor of ice cream. Safflower is a water-soluble pigment with a brilliant color and good light stability. Another good option is annatto, although the dose of use is limited by food regulations and perhaps for this reason its use has been reducing for some time now.

Figure 12. Orange sorbet

Oranges: Carotenoids are the most suitable natural dyes to produce orange tones. Beta-carotenes in particular are the most common pigments in the carotenoid family and are widely used in different food products, such as dairy, ice cream, prepared foods, and beverages. Its shades range from yellow to red, through orange, are fat soluble and are found in many cereals, vegetables, fruits and other plants. One of the main sources of extraction is the orange carrot. There are varieties of this carrot rich in this compound that are used to obtain concentrated juices rich in beta-carotene. This pigment has good stability to heat, light and is compatible with a wide pH range. Although this pigment is not soluble in water, there are some solutions, such as macro-emulsions or encapsulates, that are suitable for food use. Orange beta-carotenes have similar stabilities to yellow ones, and as in the previous case, for the production of clean label products, concentrated juices can be used.

Figure 13. Pistachio and mint ice cream

Greens: Chlorophyll and its derivatives are the most common natural source to obtain ice creams with green tones. Chlorophyll has a greenish-yellowish hue typical of pistachio ice creams, but has low light stability. This instability of chlorophylls has been largely remedied in the case of cupric chlorophyllins because the binding of copper to the chromophore increases its stability to heat and light. Copper chlorophyllin provides very attractive bright and intense green tones, but in the case of products destined for the North American market, it must be borne in mind that the FDA does not allow its use in making ice cream.

In addition to the use of chlorophyll and its derivatives, greens can also be obtained by resorting to the preparation of mixtures. For example, curcumin can be mixed with carbon black to obtain a yellowish green or spirulina in combination with some yellow pigment.

Reds: In making ice cream, there are many flavors that combine with the color red. Unfortunately, the options for making red ice creams are limited since carmine has recently been banned and anthocyanins, the main source of natural red coloration, are normally unstable at the neutral pH of ice creams, although as we will see later there are some exceptions.

Figure 14. Black Forest frozen dessert

Some of the alternatives to anthocyanins that can be used in making ice cream, although with certain limitations, are red beets, lycopene and some red carotenoids.

Carmine is one of the most stable natural pigments against heat and exposure to light. Carmine is obtained from dehydrated insects (mealybugs) that are boiled in ammonia or in a sodium carbonate solution, the solution is filtered, and alum is added to precipitate as an aluminum complex. Especially under neutral pH conditions there are no alternatives with similar tone and stability properties, but their use has recently been banned in the ice cream industry, and since the neutral pH of ice cream prevents the use of most anthocyanins, the only Natural red pigments suitable for ice cream are beets and lycopene, (the latter also with limitations in the European Union). The main reason the industry has been forced to replace carmine in ice cream is the change in the EU regulation EC No. 1333/2008, through which the use of carmine lacquers and complexes was prohibited in ice creams. Other reasons to replace carmine have to do with the animal origin of the pigment. Furthermore, carmine has been increasingly linked to allergic reactions, exacerbating its rejection. With all this, the red colorations of ice cream are mainly based on beets, even though beets and carotenoids are clearly inferior to carmine.

Unprocessed carminic acid, unlike its lacquers and aluminum complexes, is allowed in the manufacture of ice cream. This is because carminic acid does not contain aluminum, necessary for obtaining stable carmine complexes and lacquers. But unlike its aluminum complexes, carminic acid is only stable at low pH. Above pH 5, carminic acid is chemically unstable.

Thus, today one of the most important applications of beets in the food industry is in the manufacture of ice cream. Beets give bright pinkish red tones and violet tones can be achieved when combined with carbon black. Its stability is not greatly affected by changes in pH, so it can be used as a food dye at different pHs. However, it does have limited stability against light and heat. Therefore, the processing to which the product is subjected has a great impact on the behavior of this dye, giving rise to its unattractive brownish tones. Today, most pink ice cream contains betaines, either from beet juice or beet extract. Fortunately, the way ice cream is produced, and its low storage temperature help the good stability of this dye. Depending on the shade of the beet (red or bluish), a different shade of ice cream may be achieved. When using a "blue" beet color, it may be necessary to add an additional color (yellow or orange) to achieve a more attractive hue.

On the other hand, red carotenoids are used to meet the demand for shades of orange to red in the manufacture of ice cream, although in general synthetic beta carotene is frequently used in practice. Stabilities to heat and pH above 3.5 of these dyes are quite good, however stability to light and oxygen is limited. As noted above, some solutions for strawberry flavored ice creams are combinations of red carotenoids and beets.

Lycopene is a natural carotenoid extracted from ripe tomatoes (there is also synthetic lycopene). The advantages of tomato lycopene are the acceptable stability to heat and pH and that it does not present unpleasant flavors. In addition, it covers the entire range of colors from practically yellow to deep red. As a drawback, it should be noted that, like other carotenoids, the hue may turn orange during homogenization. Therefore, if possible, color should be added after pasteurization to prevent degradation.

As we said before, although anthocyanins have not historically been considered the most suitable coloring compounds for making ice cream due to their neutral pH, recent research qualifies this belief as we will see later. Anthocyanins are water soluble pigments, responsible for the bright red color of plants and their tone depends on their origin and the pH of the medium. The lower the pH, the more reddish and less bluish is its tone. Above pH 4.5, most anthocyanins become unstable, leading to color loss. The most common anthocyanins in the coloring of sorbets (sorbets are not properly ice cream since they do not contain dairy and their pH is acidic). The most widely used anthocyanins are obtained from black carrots and grapes, due to their greater stability, but they can also be obtained from other vegetables such as elderberry.

In addition to what has been said, recent studies on anthocyanins have shown that those anthocyanins with acylated substituents are more resistant to discoloration at higher pHs than their non-acylated analogues. In addition, acetylation of the molecular structure also increases its stability during processing and storage. The forms of anthocyanin that coexist in an aqueous medium are flavylium cation, carbinol pseudobase, quinonoidal base and chalcone. When the pH is very acidic (pH <2), the flavillium cation is the most abundant. At a pH between 2 and 4, in addition other quinonoidal structures coexist, and in this pH range is where the stability of anthocyanins is maximum. If the pH is increased, ionization of the hydroxyl groups forms the anionic blue quinonoidal unstable species and at pH 5 and 6, the non-acylated anthocyanins are unstable and rapidly discolor. Some researchers have confirmed the unusual stability of acylated anthocyanins at a pH above 5.0, attributing the improvement in their stability to the accumulation of acyl groups in the pyryl ring of the flavylium cation. This gives them a special molecular structure that reduces the susceptibility of nucleophilic attack to water with the subsequent formation of a pseudobase or chalcone. In particular, acetylations at the 3 'and 7 carbons of some specific pigments of plants of the Orchidaceae and Asteraceae family, give them the maximum protection against hydrolysis. Thus, this new avenue of research seems to lead us to the use of some sources rich in acylated anthocyanins (mostly di or poly-acylated), such as black carrot and red cabbage, more resistant to basic and neutral pH than dyes rich in unacylated anthocyanins from other sources such as red grapes.

This would explain why acylated anthocyanins, like those of black carrots, can be more easily applied to neutral and slightly alkaline products such as ice cream. Specifically, the black carrot has 5 acylated anthocyanins in its composition, the majority derived from cyanidin, which makes it more resistant to changes in pH. In practice, in addition, the performance of this variety of carrot as a colorant is very high, and its pleasantly fruity flavor allows to increase the doses without negatively affecting the taste of the final product.

On the other hand, the use of its anthocyanins contributes to an excellent bright strawberry red tone in acidic products, up to pH 4.5. Above this pH, its behavior is very interesting in applications close to neutrality, where it exhibits shades ranging from mauve to blue. Furthermore, it does not present high levels of polyphenols that can interfere with the composition of many matrices and generate undesirable precipitates.

Red cabbage, on the other hand, contains around 15 anthocyanins that are derivatives of cyanidin-3-diglucoside-5-glucoside acylated with various hydroxycinnamic acids, including ferulic and / or coumaric. This gives it great stability against light and heat, in addition to pH, however, changes in this last parameter must be considered due to variations in tone. These anthocyanins impart a bright pink color at low pH on light bases and pink / mauve shades on white bases when pH is increased. However, the contribution of undesirable flavors or odors is one of the challenges to overcome today.

Brown: Caramel is the most widely used natural brown pigment. Compared to other natural brown dyes, caramel has a higher coloring capacity and therefore exceeds other products used with lower doses. Caramel shows very good light and heat stability. Caramel is normally used as a coloring for warm flavors such as coffee, toffee and caramel. At low doses, caramel is also applied to impart color to vanilla ice cream. To produce very dark brown tones, they can be mixed with red pigments. Caramel colors burnt sugars and aromatic caramels find application, for different purposes, in many products related to the ice cream industry.

Figure 15. Chocolate and caramel ice cream

A very interesting alternative in the elaboration of some ice creams is burnt sugar. The burnt sugar is produced by carefully controlled heating of sucrose without the addition of additives. It has coloring and flavoring properties. In the European Union, burnt sugar is considered a food, so it does not require labeling as a dye (clean label). Its excellent stability to light and heat makes burnt sugar a very interesting choice for brown tones in the ice cream industry.

Burnt sugars are produced simply by heating sugars; Chemical reagents are not allowed to promote caramelization or to adjust the final pH. Consequently, they may correspond to the definition of both food ingredient and food color. If they add a noticeable flavor to the final product, then they can be declared as "burnt sugar" or "caramelized sugar" (avoiding the E number on the label), whereas in case their main function is to impart color, then they should be considered as additives food and should be labeled "E150a". They are characterized by a yellowish, reddish brown tone and, in general, by a lower intensity of color compared to catalyzed caramel colors.

Another alternative is the use of aromatic caramels. These products are light brown in color and are also obtained by controlled heat treatment of sugars of different types. They are food ingredients, used mainly as a coating or layers with the dual purpose of improving the flavor and improving the image and attractiveness of the final product. Aromatic caramels can offer a wide range of flavors (their main function) but they can also be used to color; Depending on the need, it is possible to choose between products capable of conferring sweet, bitter or burnt notes to ice cream.

In addition to burnt sugar and aromatic caramels, there is a wide range of caramel colors (E150) available for making ice cream. Caramel colors are food dyes produced by heating carbohydrates to controlled temperature and pressure in the presence of food grade chemicals used to promote caramelization. Depending on the catalysts used during the production process, they are divided into four classes (E150a, E150b, E150c and E150d). Although caramel colors are typically brown, each class is characterized by its own hue, ranging from yellow to reddish brown, from light brown to dark brown.

Burnt sugars and caramel colors E150d can be added to chocolate, coffee, caramel, chestnut, hazelnut and vanilla ice creams to improve their brown color and also to homogenize it between different batches. E150d caramel color is recommended when a dark brown black shade and high efficiency are required. This type of dye, in fact, is characterized by a high coloring power that allows reaching the desired color with little amount of dye. So this is the best solution when you need high performance with low cost. On the other hand, this caramel must be declared a food additive and labeled "E150d".

Burnt sugars are the best option to give ice cream a light brown hue due to its typical hue and color intensity. Furthermore, burnt sugars also add their unique flavor to the final product and do not affect the opportunity for clean labeling.

E150d caramel color and burnt sugar (both in liquid and powder form) are helpful in enhancing the color of the chocolate coating on ice cream bars. The former is best suited for dark chocolate, the latter is perfect for giving golden chocolate a yellowish hue.

As for aromatic caramels, they can be added to ice creams with a double function. In fact, they can be mixed with the product to improve its flavor and make it more appetizing. Also often they used as waves or spikes, improving the visual appeal of the final product and also making it more attractive; For this purpose, in some cases, aromatic caramels containing thickening agents can be used to improve their fluidity and pouring capacity and adjust them to the characteristics of the ice cream.

But caramel colors are not only used in making ice cream paste, they are also frequently used in making cookies and cones. In fact, the intensity of the color and tone of the cookies used in the ice cream cookie sandwiches can be improved by adding caramel or burnt sugar; In this case, a small percentage of E150d is enough to give them a dark brown color, while burnt sugars are best suited to produce lightly colored brownies. In this application, the E150c caramel colors are also suitable; represent the most suitable solution when a light brown to dark red tone is desired.

Burned sugars are also often used in the production of ice cream cones; In fact, the addition of burnt sugar to the recipe of cones can be very useful to improve and stabilize its typical light brown color. In addition, this natural ingredient helps improve its flavor. In this case, powdered and liquid burnt sugars work well.

Finally, in the iced cola, the addition of small amounts of double strength E150d caramel color allows to achieve the typical color intensity and tone that characterize cola soft drinks.

Interactions between ingredients, process conditions and colorant

As it has been commented in the previous sections, the pH, temperature, light, and other variables of the process have a great importance in the stability and tone of the different coloring substances. Not all colorants respond in the same way, and color stability plays a role in these selections, but likewise, the colorant can affect ice cream's technological properties, stability, and flavor. Let us see all this below.

When dosing the dye, for example, it should be borne in mind that dairy fat emulsions have a whitening effect on ice cream. Therefore, the higher the fat content and the smaller the size of the emulsified fat drops, the whiter the product is, since these act as a coating bleaching agent. Milk proteins also scatter light, which contributes to the whitening effect of ice cream. Therefore, to achieve intense color tones in products that contain high amounts of protein and fat, higher color doses are required.

A similar effect on color takes place during the overrun since the incorporation of air also has a whitening effect. Therefore, when calculating the dose of dye to be used, it should be borne in mind that the tones of the finished ice cream will be paler compared to the liquid ice cream mix before the overrun.

Another very important aspect, as has already been mentioned on several occasions, is that ice creams, due to their high dairy content, have neutral or slightly basic pH's, which has a notable effect on the stability of non-acylated anthocyanins and acid carmine, among other pH sensitive dyes. This is not the case when dyes are used in the production of sorbets (in fact, a sorbet is not properly an ice cream), since its pH is usually acidic and it is possible to use pigments such as anthocyanins or black carrot juices with easier. Keep in mind that one of the main differences between sorbet and ice cream is its pH and a low pH increases the possibilities of anthocyanin-based red tones.

Another key issue is the stability of the dye against elevated temperatures. As it has been possible to verify the pasteurization stage it is essential in the production of ice cream. Therefore, depending on whether the dye is more or less stable at temperature, it may be incorporated in the stages prior to pasteurization, or it must be added later under sterile conditions. Additional operational complexity that is usually justified by the natural origin of heat-sensitive dyes.

Regarding the use of fruit-based ingredients, it should be borne in mind that the addition of these ingredients has a strong impact on the background color of the ice cream. However, due to the heterogeneity of the fruit and its state of maturity, it will be necessary to add color to compensate for this variability and improve the visual attractiveness, since the final shade of the product will largely depend on the colors of the added fruit.

Another important stage is the homogenization of the mixture since this operation affects the color tone when dispersed pigments are used. In this case, the particle size of the coloring substance has a great impact on how color is perceived by the human eye. When lacquers, emulsions or any type of colorant are applied in the form of a stable dispersion, a smaller size of the drops or particles gives rise to more intense and brighter tones. This is for example the case of carotenoids solubilized in small drops of oil. The smaller the size of these drops, the more intense the yellow color is, so if the pigments are added before homogenization, the cutting forces will reduce the particle size, thus improving the color.

Regarding the use of emulsifiers in the formulation of ice cream, the added colors may exhibit different binding properties with proteins of vegetable or milk origin, depending on the type of emulsifier used. And this has an important effect, especially when ice cream melts, since when the emulsifier facilitates the binding of color to proteins, the color is retained in the fat-protein phase. In this case, therefore, the aqueous phase will be less colored than the fat-protein phase. But when the emulsifier does not facilitate the binding of the color to the proteins, almost all the color migrates towards the aqueous phase, giving rise to an intensely colored background.

Finally, possible interactions between colorants and flavorings should be considered. Thus, for example, when certain carotenoids are applied in high doses, strange flavors may appear. But flavorings can also degrade color, as some solvents or oils used in flavoring have a destabilizing effect on the colorant if they come into direct contact.

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