Food Science and Technology Notes

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BEHAVIOR OF ICE CREAM CONSTITUENTS UPON HEATING

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There is an art to making a good ice cream, but the process requires the application of a number of scientific principles. The procedure is somewhat analogous to that followed by an analytical chemist. A chemical determination is based on precise scientific principles, but to perform the analysis requires a great deal of art. It is thus possible to be well versed in the art, or be a good technician, without actually understanding the underlying principles.

Ice cream making is a complex process, many aspects of which are still poorly understood. When problems arise, an attempt is often made to solve them by empirical means based on experience in similar situations or even on intuition. The problem of shrinkage is a typical example. When it is encountered, all conceivable corrective measures are undertaken; yet often the problem finally disappears without leaving any clue as to what caused it and which measures corrected it. This state of affairs may be considered rather unsatisfactory, but it is encouraging to know that a number of investigators have in recent years undertaken studies which in time should provide the needed understanding and awareness of the applicable principles. Through such efforts, it is hoped, the art will not always remain ahead of the science involved in making ice cream.

This series of papers will consider the effect of heat on various ice cream constituents. When milk or its products are heated, certain physical and chemical changes occur that may or may not be desirable. A certain amount of heating is unavoidable, as it is required in compliance with the pasteurization laws. In ice cream making, the required heat treatment is of sizable proportion but only of minimum intensity. A number of manufacturers use a more intense treatment than is required by regulations.

Specifically, the following changes are brought about by heat treatment:

Destruction of bacteria and enzymes. This is a first priority effect, but one that can normally be quite well controlled. Unless the purpose is to make a completely sterile mix, the pasteurization standards are sufficiently rigid to

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insure a very low rate of surviving bacteria and freedom from troublesome enzymes. If bacterial problems are encountered, the damage is probably due to undesirable bacterial growth prior to pasteurization or post-pasteurization contamination. If an enzymatic problem is encountered, such as lipolytic rancidity, it almost invariably has occurred prior to pasteurization.

Effect on milk proteins. There are principally two classes of proteins in milk, called casein and the whey proteins. Both are complex mixtures of a number of individual proteins. Casein by itself is quite stable to heat, whereas the whey proteins are definitely heat denaturable. When casein is heated in the presence of whey proteins, which is the case in an ice cream mix, the heat stability of the casein is considerably reduced.

When casein is partly destabilized by heat, it agglomerates in such a way that it entraps some of the liquid portion of the mix within its structure, resulting in an increase in viscosity. The extent of the casein structure that develops depends on a number of factors, such as the previous heating history of the milk, the salt balance, pH, the manner in which the heat treatment is applied, and the whey protein content. It appears that this is the phenomenon that takes place when a concentrated milk or an ice cream mix is superheated. The resulting reduction in free water content is desirable from the standpoint of producing an ice cream with a desirable body and texture.

The superheating effect may be considered desirable, but proceeding simultaneously is the development of what is commonly described as a cooked flavor. This defect is partly explained by the effect of heat on the sulfur-containing whey proteins. The sulf-hydryl groups that are thus activated may be involved in the production of hydrogen sulfide which, in turn, is involved in the cooked flavor. On the other hand, the sulfhydryl groups impart some natural protection against the development of a cardboardy, oxidized flavor, which is extremely objectionable.

Effect on sugars. The degree of heat normally used in conventional batch or HTST pasteurization has little effect on sugars used in ice cream. In the manufacture of a sterile or powdered ice cream mix, however, a browning may be observed, together with a caramel-like flavor. The brown color is probably due to an interaction of sugar with casein or some breakdown products of the milk proteins. When extremely high temperatures are used, the sugar itself may caramelize, also causing a brown color.

Prolonged exposure to high temperature may cause a degradation of milk sugar, with accompanying formation of acids and aldehydes. Formic, acetic, and lactic acids have been reported to be formed in this manner.

Effect on milk fat. Surprisingly little is known about the effect of heat on the properties of milk fat. The colloidal emulsion of milk fat rarely occurs among natural fats. The fat globule membrane, both natural and that formed by homogenization, is largely responsible for the physical, chemical, and colloidal properties of fat. Thus, any process that alters the composition or orientation of the membrane may reasonably be expected to alter the properties of the emulsion.

There are some indications that the fat in milk may interact with proteins, but the facts are not too clearly established. Some aspects of this process will be discussed in a subsequent paper. More research is definitely needed in this phase of dairy chemistry.

Effect on milk salts. The most interesting effect is the removal of calcium and phosphorus from solution. Although the process is largely reversible, there may be evidence of its having taken place.

Calcium ions are involved in a number or properties of ice cream. To a great extent, the effect of heat on the colloidal properties of milk proteins results from the effect of heat on calcium ions. The physical structure of the calcium-caseinate as it naturally occurs in milk will undergo alterations with changes in the concentration of calcium. A high calcium content in relation to certain other milk salts exerts a destabilizing effect on the milk proteins and may also give rise to excessive clumping of fat globules.

Calcium is not unique in its effect on colloidal systems. Minerals with similar chemical properties, such as magnesium, produce effects analogous to those of calcium.

Miscellaneous effects. It is a well known fact that developed acidity may cause excessive viscosity or even coagulation of the ice cream mix upon heating. High viscosity may in turn cause excessive pressures and slow cooling in the pasteurization equipment.

The action of ice cream stabilizers is affected by heat, but not all stabilizers behave in the same manner. In some cases, there is evidence of an interaction between the stabilizer and some of the milk constituents, and the extent of this interaction may depend on the amount of heat treatment. In other cases, increasing the heat treatment may cause some degradation of the stabilizer, or it may improve the action of the stabilizer by improving solubility.

There are indications that heat treatment is responsible for a reduction in certain vitamins. Vitamins C, B_1, and possibly A may be at least partly destroyed. The rate of destruction increases with more intense heat treatment. There is also a possibility that some of the essential amino acids may be slightly reduced. Lysine and methionine primarily are affected. It appears, therefore, that heating, particularly at high temperatures, may have some adverse effect on nutritive value, but evidence indicates that it is not significant.

The most intriguing effects of heat are the various interactions that occur among the milk constituents. When heat is applied to only one milk constituent, the results generally follow a predictable pattern. When two or more constituents are present, a departure from predictable behavior is observed that may be attributed to interaction. Thus, certain milk proteins may interact with other milk proteins and also with other milk constituents. Further complications arise from such factors as the difference in behavior of milks from different sources, seasonal differences, the temperature history, and even the type of processing equipment.

The true facts are hidden in what may be termed a complicated jigsaw puzzle. It will require a great deal of searching and contemplation before the last piece of the puzzle is fitted into its proper place.