Module 6. Physico-chemical properties of ice cream mixes and ice cream

Lesson 16
PHYSICO-CHEMICAL PROPERTIES OF ICE CREAM MIXES-I

16.1 Introduction

The ice cream mix is a complex colloidal system. It is both an emulsion and a foam. The milk fat exists in tiny globules that have been formed by the homogenizer. The fat globules are in coarse dispersion. Some constituents occur in true solution (sugar, lactose and salts) others are colloidally suspended (casein micelles, stabilizers,insoluble sweetener solids and some calcium and magnesium phosphates).

16.2 Mix Stability

Mix stability refers to the resistance to separation of milk proteins (in colloidal suspension) and milk fat (in emulsion). Instability results in separation of fat globules due to creaming, protein particles as coagulated or precipitated material or a clear serum of whey from mix or melted ice cream.

Generally, ice cream mix is homogenized to reduce the relatively large fat globules to fine particles (mean size 0.5 – 1.0 µ and a maximum size of about 2 µ) with a high degree of dispersion. These fat globules are kept from creaming due to their small size after homogenization, the increased density (due to the addition of protein and stabilizers), and the high viscosity in the mix due to the addition of proteins and stabilizers. The optimum stability is that which allows the mix to pass through the processing stages (especially the plate-type pasteurizer in which plates may be pushed apart by high viscosity mixes) while permitting whipping and freezing process to destabilize an adequate amount of fat. The displacement of proteins by emulsifiers helps create this optimum in stability by weakening the emulsion **(Fig. 16.1)**

Protein stability results from the state of the proteins and the appropriate balance in the solution of pH and salts. Excessive heat in pasteurization, e.g. may denature the whey proteins, leading to their adsorption to casein micelle and eventual precipitation. Likewise, any change in solvent conditions may lead to enhanced protein precipitation.

Whey separation from mix generally arises from phase separation between milk proteins and polysaccharide stabilizers. Stabilizers tend to move apart from each other (even though they are hydrophilic) leading to formation of clear serum layer in the mix after standing or to leakage in serum from ice cream during melting. To prevent this from happening carrageenan is normally added as a secondary stabilizer.

16.3 Density of Mixes

The density or specific gravity(density relative to water) of ice cream mix varies with its composition. Measurements of specific gravity can be made with a hydrometer and of density by weighing a known volume of mix at a known temperature on a gravimetric balance. Density can also be calculated based on composition. Investigations indicate that the density of mix may vary from 1.0554 to 1.1232 g/ml, with an average for a 10% fat mix of approximately 1.1 g/ml.

The density (D) of the mix can be calculated as follows

$$\text{Density of mix} = \frac{100}{\frac{\%\ \text{Fat}}{0.93} + \frac{\%\ \text{MSNF}}{1.58} + \frac{\%\ \text{Water}}{1}}$$

16.4 Acidity of Mixes

The normal titratable acidity of mixes varies with the percentage of MSNF and may be calculated by multiplying the percentage of MSNF by the factor 0.017. Thus, a mix containing 11% MSNF would have a normal titratable acidity of 0.187% lactic acid. The normal pH of ice cream mix is about 6.3. The acidity and pH are related to the composition of the mix – an increase in MSNF raises acidity and lowers pH.

If fresh milk components of excellent quality are used, the mix can be expected to have a normal acidity. The apparent or natural acidity of ice cream mix is caused by milk proteins, mineral salts (mostly citrates and phosphates) and dissolved carbon dioxide. Developed acidity is caused by the production of lactic acid by bacterial fermentation of the lactose in dairy products. When the acidity of the mix or ice cream is above normal, developed acidity is probably present in the dairy products used in the mix. A high acidity is undesirable as it contributes to excess mix viscosity, decreased whipping rate, inferior flavour and a less stable mix. The latter may contribute to ‘cook on’ during processing and pasteurization, because heat and acidity accelerates the denaturation of proteins.

16.5 Freezing Point

The freezing point of ice cream is dependent on the concentration of soluble constituents and varies with composition. The freezing temperature can be calculated with considerable accuracy and can also be determined in the laboratory with a cryoscope or avapour pressure osmometer.

An average mix containing 12% milk fat, 11% MSNF, 15% sugar, 0.3% stabilizer and 61.7% water has a freezing point of approximately –2.5°C. The freezing point of mixes with higher sugar and MSNF contents may range downward to –3°C while for mixes with high fat, low MSNF or low sugar content it may range upward to –1.4°C. Generally, the differences in type and amount of sweetener solids and lactose concentration used in the mixes are primarily responsible for the differences in freezing points of mixes.

The initial freezing point of ice cream mix is highly dependent on the sweetener content of the mix. When latent heat is removed from water and ice crystals are formed, a new freezing point is established for the remaining solution since it has become more concentrated in respect to the soluble constituents. A typical freezing curve for ice cream shows the percentage of water frozen at various temperatures. **(Fig. 16.2: Water crystal formation in ice cream)**

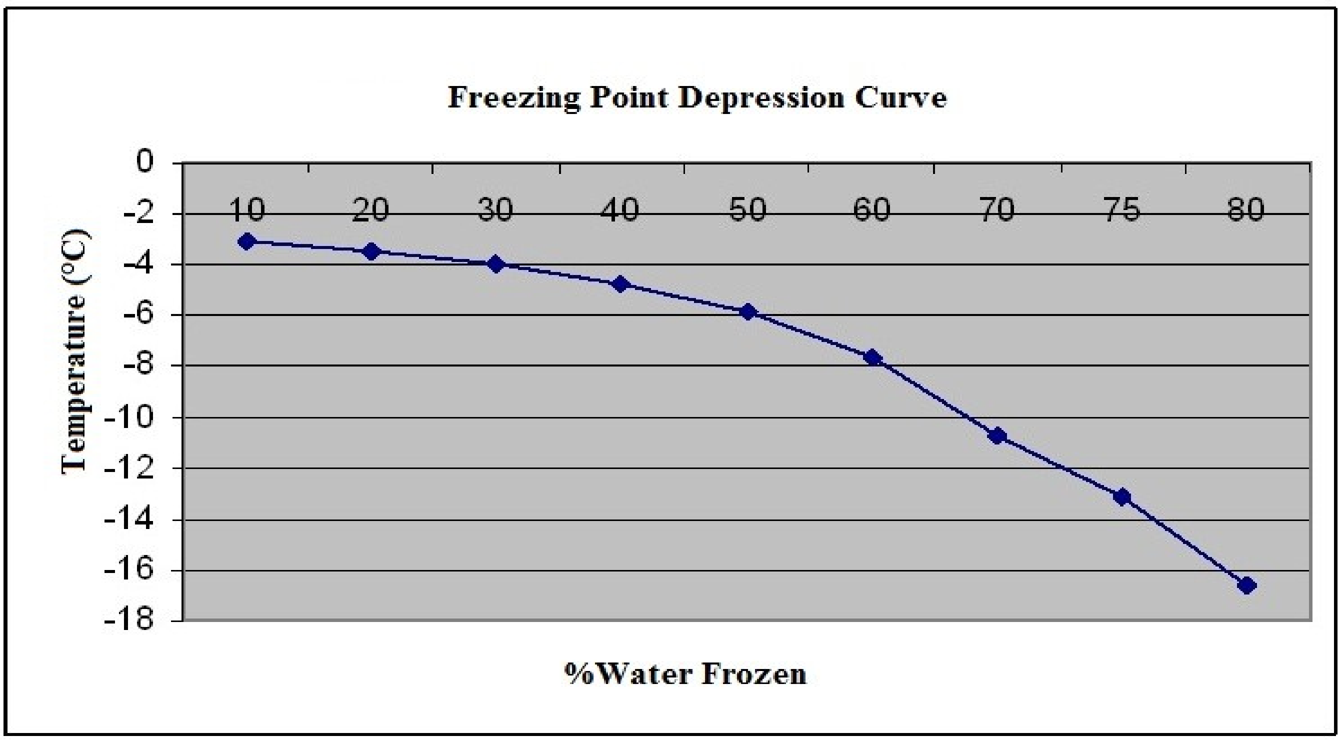

Fig. 16.3 A typical freezing point curve for ice cream mix

16.5.1 Freezing point depression

When a solute is added to water the physical properties of freezing point and boiling point change. Water normally freezes at 0^{o}C and boils at 100^{o}C. As more solute is added, the freezing point drops ("freezing point depression"). The freezing point depression ΔT_f is a colligative property of the solution, and for dilute solutions is found to be proportional to the molal concentration c_m of the solution:

$$\Delta T_f = K_f c_m$$

Where K_f is called the freezing-point-depression constant.

16.6 Mix Viscocity

The viscosity of the liquid is important. If the liquid is too viscous, it is difficult to beat and therefore to incorporate the air; if it is not viscous enough, the film between the air bubbles rapidly drains, and the bubbles coalesce.

Viscosity, the resistance of a liquid to flow is the internal friction that tends to resist the sliding of one part of the fluid over another. If viscosity is constant, regardless of the applied stress, the liquid is said to be Newtonian and the viscosity can be reported. An example of Newtonian liquid is water. Ice cream mix however, is pseudoplastic. As the shear rate increases, the viscosity decreases. Thus, to characterize the viscous behavior of an ice cream mix, both the underlying viscosity and the shear rate dependence are necessary. The term ‘apparent viscosity’ is often used to describe the viscosity of a pseudoplastic material at one shear rate e.g. 25 mPa.s. Also, ice cream mix exhibits thixotropy, which means that its apparent viscosity also decreases with time of applied shearstress. A defined pre-shearing time is thus required before the underlying viscosity can be measured.

The mix viscosity can be measured in three ways

1. By the time required to flow under a fixed pressure through a pipette or specially constructed tube.

2. By measuring the force required to move one or two parallel plates or coaxial cylinders between which a layer of liquid sample is placed or

3. By measuring the fall of a ball through a column of mix

Some instruments used to measure viscosity of ice cream mix are Falling Ball Viscosimeter, Haake Viscosimeter, Brookefield Viscometer and Ostwald viscometeretc.

A certain level of viscosity isessential for proper whipping and retention of air. The viscosity of the mix isaffected by

- Composition: viscosity increases with increasing concentration of stabilizer, protein, corn syrup solids, fat and total solids, with the contribution of each decreasing in that order (i.e. stabilizer has more influence on mix viscosity than does fat). Also heat and salts (such as calcium, sodium, citrates, phosphates)can affect viscosity due to their effect on casein and whey proteins.

- Processing and handling of the mix: elevated pasteurization temperatures, increasing homogenization pressures and ageing for up to 4 hours will each increase viscosity of the mix.
- Temperature: as with all fluids, viscosity is temperature dependent, so decreasing storage temperature will result in increased mix viscosity.

Although much has been written about the causes and effects of differences in viscosity, there is no final answer to the question of how much is desirable in ice cream mixes. A high viscosity was believed to be essential at one time, but for fast freezing (rapid whipping) in modern equipment, a lower viscosity seems desirable. In general, as the viscosity increases, the resistance to melting and the smoothness of texture increases, but the rate of whipping decreases. The mix should be properly balanced (in regard to composition, concentration, and quality of ingredients)and then properly processed to produce the desired whipping ability and body and texture. Under these conditions a desirable viscosity is assured.

Viscosities of ice cream mixes are affected by temperature; the concentration, type and degree of hydration of the stabilizer, carbohydrates, colloidal salts and proteins of the mix; type of heat treatment; whether the mix is homogenized prior to holding; and the rate of shear in the holding tube. When shear rates varies from 50 to 180 s^{-1} , the viscosities at 80°C ranges from 8.7centipoise (cP) in an unstabilized mix to 103 cP in mix containing 0.25% Carboxy Methyl Cellulose; the mixes had 14% fat and 41% total solids.