Module 3. Ingredients in ice cream and frozen desserts

Lesson 7
STABILIZERS AND EMULSIFIERS-CLASSIFICATION, TYPES, PROPERTIES AND ROLE IN ICE CREAM

7.1 Introduction

Ice cream is a complex food colloid that consists of air bubbles, fat globules, ice crystals and an unfrozen serum phase. Ice crystals and air bubbles are generally in the range of 20–50 μm. The air bubbles are usually to some extent coated with fat globules and the fat globules are coated with a protein/emulsifier layer. The serum phase consists of the sugars and high molecular weight polysaccharides in a freeze-concentrated solution. Various steps in the manufacturing process, including pasteurization, homogenization, ageing, freezing, and hardening, contribute to the development of this structure. Proteins and emulsifiers compete for inter facial space during the homogenization of the fat and the creation of the mix emulsion. Following homogenization, the emulsion is further affected by changes occurring during the ageing step, viz.,crystallization of the fat and rearrangement of the fat globule membrane to the lowest free energy state. This emulsion then undergoes both whipping and ice crystal formation during the dynamic freezing process, which contributes to the development of the four main structural components of the frozen product: discontinuous foam, a network of partially coalesced fat surrounding the air bubbles, ice crystals, and a continuous, freeze-concentrated, unfrozen aqueous solution

Stabilizers and emulsifiers have been conventionally used in ice cream as additives. Recently, there has been a tendency towards ‘all natural’ or ‘natural’ products which have given rise to the so called premium ice cream which is supposed to contain no additives. Yet because of the quality enhancing ability of stabilizers and emulsifiers, they remain as important ingredients for most ice creams and frozen desserts.

Stabilizers are substances which make it possible to maintain the physico-chemical state of a foodstuff; stabilizers include substances which enable the maintenance of a homogenous dispersion of two or more immiscible substances in a foodstuff and include also substances which stabilize, retain or intensify an existing colour of a foodstuff. Emulsifiers are surface active agents which improve the sensory quality of ice cream by aiding the whipping process, improve air cell distribution and enhance the products heat shock resistance.Despite their name, emulsifiers are actually used in ice cream to de-emulsify

some of the fat.

7.2 Stabilizers

Stabilizers are a group of water-soluble or water-dispersible biopolymers used in small amounts (typically 0.2%) in ice cream, sorbets, water ices and other foods. Most stabilizers are polysaccharides of plant origin, *e.*g. alginates and carrageenans (from seaweeds), locust bean gum and guar gum(from tree seeds), pectin (from fruit) and sodium carboxymethyl cellulose (from cotton). Xanthan, a bacterial polysaccharide, and gelatin, a polypeptide of animal origin, are also sometimes used. These biopolymers are polydisperse and polymolecular, because their structures vary with the source and the environmental conditions. Nutritionally, stabilizers are a source of solublefibre. Although they come from natural sources, under European law they are considered food additives and therefore they have associated ‘E numbers’.Stabilizers are straight or branched polymers containing hydroxyl groups that can form hydrogen bonds to water molecules. Typically they contain numerous monomer units and have molecular weights of 10^5-10^6. Because they are large, stabilizers do not dissolve in water as readily as smaller molecules: some require high temperatures or shear for complete hydration. When dissolved, they produce high viscosity solutions at low concentrations. Some stabilizers in solution can form gels when heated and/or cooled or on the addition of cations.

7.3 Role of Stabilizers in Ice Cream

In ice cream, stabilizers, usually used in combination of 2-3 types are primarily used for the following purposes:

- To increase the viscosity of the mix.
- To stabilize the mix i.e. to prevent wheying off
- To help in suspension of flavouring particles.
- To produce a stable foam with desired stiffness at the time of packaging
- To reduce or slow down the growth of lactose crystals during storage mainly during temperature fluctuations.
- To reduce moisture migration from the product to the package or the air.
- To help prevent shrinkage of the product volume during storage.
- To provide uniformity to the product and resistance to melting.
- To produce smoothness in texture during consumption.

- Reduce the rate of meltdown (i.e. the rate at which ice cream melts).
- Prevent shrinkage and slow down moisture migration out of ice.
- Mask the detection of ice crystals in the mouth during eating.
- Allow easier pumping and more accurate filling during processing.
- Facilitate the controlled in corporation of air in the freezer.

7.3.1 Classification of stabilizers

Stabilizers which are used in ice cream and frozen desserts mainly fall into the following categories

1. Proteins- Gelatin
2. Plantexudates – Arabic, ghatti, karaya and tragacanth gums
3. Seed gums – Locust (carob) bean, guar, psyllium, starch and modified starches
4. Microbialgums – Xanthan
5. Seaweed extracts – agar, alginates, carageenan
6. Pectins– low and high methoxyl
7. Cellulose– sodium carboxymethyl cellulose, microcrystalline cellulose, methyl and methylethyl cellulose, hydroxypropyl and hydroxypropylmethyl cellulose.

7.3.2 Properties of individual stabilizer ingredients

a) **Sodium Alginate**

Sodium alginate (E401) is a polysaccharide of guluronic acid and mannuronic acid. It is extracted from brown seaweeds such as *Macrocystispyrifera* and *Laminaria digitata*. It consists of a negatively charged polymer chain with ionic bonds to positively charged sodium ions (Na+). In aqueous solution, the sodium ions dissociate from the polymer so it becomes charged. Calcium ions (Ca^{+2}) or other doubly charged cations can bind to negative charges on two different polymer molecules. These intermolecular interactions lead to the formation of a gel. In ice cream, alginates are blended with phosphate, citrate or tartrate ions to prevent premature gelation due to the calcium from the milk solids. The major advantage of alginate is its resistance to acid conditions, particularly when heated, whereas other stabilizers would lose their functionality. Usually, it is used at a level of

0.18-0.25%.

Alginic acid extracted from kelp is insoluble in cold water; hence salts of organic acid are prepared or the propylene glycol ester which is readily soluble in hot or cold water is prepared. This product is known as propylene glycol alginate.

b) Carrageenan

Carrageenans (E407) are complex polysaccharides of esters of galactose and m-3,6-anhydrogalactose,found in red seaweeds *(Rhodophycae),* such **as** *Chondrus crispus* (IrishMoss), *Kappaphycus alverezii* and *Eucheuma denticulaturn.* Carrageenancan have several structures, usually classified as one of three types that have different properties: *kappa* (k), *iota* **(i)** and *lambda (l)* . Carrageenans can also form gels with both milk proteins and locust bean gum. In ice cream applications, k -carrageenan fractions are frequently used not as a primary stabilizer but as a secondary hydrocolloid to prevent wheying off of mix, a condition promoted by the other stabilizers due to their incompatibility in solution with milk proteins. Hence, it is included in most blended stabilizer formulations at a usage rate of 0.01-0.05%. At higher concentrations the carrageenan would begin to gel and fail to function well. k -carrageenan reduces phase separation of milk proteins and polysaccharides which could result in wheying off.

c) Locust Bean Gum

Locust bean gum (E410), also known as LBG, carob gum or St Johns Bread, is extracted from the seeds of the Mediterranean *Ceratoniasiliqua* tree. These large, evenly sized seeds were the original carats used as a measure of weight. LBG is a polysaccharide consisting of a mannose backbone with galactose side branches on about a quarter of the mannose units.The side branches occur in blocks, giving LBG ‘smooth’ regions of free mannose backbone and ‘hairy’ regions of galactose side groups. In solution, strong hydrogen bonds can form between the large smooth backbone regions. This leads to gel formation under certain conditions. LBG is the best stabilizer for many ice cream applications and its ability to gel is crucial to some aspects of its use. However, it is also expensive stabilizer.

d) Guar Gum

Guar gum (E412) is extracted from the seeds of *Cyamposistetragonolobus,* an annual crop grown in the Indian subcontinent. Guar has a similar structure to LBG: it has a backbone of mannose units, about half of which have galactose side branches. Guar has a higher molecular weight than LBG and the side groups are more evenly spaced. The larger proportion of galactose units makes guar cold water soluble. The regions of backbone that are free of side chains are smaller than in LBG. Hydrogen bonding between them is therefore not strong enough to form permanent cross-links, but does result in‘hyper-entanglements’. These are stronger than purely topological entanglements and account for the high viscosity of guar gum solutions at low concentrations.Guar gum is significantly

cheaper than LBG. Both these gums at 0.1-0.15% impart a chewy body to the product. While locust bean gum may cause a comparatively short body, guar gum may impart stickiness to the product.

e) Pectin

Pectin (E440) is extracted from citrus peel and apple pomace. It is a polysaccharide consisting of linear chains of galacturonic acid and galacturonic acid methyl ester units. Pectin is classified according to its degree of esterification. High methoxy *(* >50% esterified)and low methoxy (< 50%) pectins possess different properties. For example,low methoxy pectin requires calcium to gel whereas high methoxy pectin gels at low pH and in the presence of high concentrations of sugar. Pectin is the setting agent used in jam making. It is used as an ingredient in syrups and fruits used in making rippled effects in ice cream and is also effectively used in sherbets and ices. All fruits contain some pectin. Some fruits,such as apples and gooseberries, usually contain enough natural pectin to form a gel, whereas pectin must usually be added to set the jam for other fruits,such as strawberries and cherries. It is not a very satisfactory stabilizer for ice cream.

f) Xanthan gum

Xanthan gum (E415) is produced by the bacterium *Xanthomonascampestris.* It is a polysaccharide consisting of a chain of glucoseresidues with charged trisaccharide side groups. Xanthan has excellent solubility and is suitable for use under acid conditions, *e.g.* in water ice. Xanthan is a rod-like polymer. In solution, the rods are oriented indifferent directions and interact to form a weak network. When a small amount of shear is applied, the rods all line up and the network is broken. When the shear is removed, the network reforms. **As** a result, the viscosity of xanthan solutions decreases dramatically with shear, but quickly recovers once the shear is removed. This property is useful in sauces for ice cream. During dispensing, the viscosity is low, but as soon as shear forces cease, the viscosity rises substantially. These results in a sauce that remains fixed after dosing onto the product. Xanthan gum provides viscosity which is stable over wide range of pH and temperature. It is effective at low levels when used along with locust bean gum and guar gum, these vegetable gums act synergistically with it. However, xanthan is not widely used in ice cream because it is expensive.

g) Sodium Carboxymethyl Cellulose

Sodium carboxymethyl cellulose (E466) is derived from purified cellulose from cotton and wood pulp. It is a sodium salt polymer of anhydroglucose residues. For use in ice cream, an average of 0.7 of the 3 hydroxyl groups in each glucose unit is substituted with a sodium carboxymethyl group. The long, negatively charged molecules produce a stable thickener that can also reduce casein precipitation. CMC hydrates at low temperatures. It has excellent water holding property but may cause wheying off. Usually used together with other gums, CMC at 0.1-0.2% performs excellently as an ice cream stabilizer. However, its perception as a ‘chemical’ has resulted in fairly low usage.

h) Gelatin

Gelatin is a mixture of high-molecular-weight polypeptides derived from collagen from animal connective tissues, and was commonly used as a gelling and thickening agent. Gelatin disperses in cold water and forms a gel upon heating the dispersion. It is used at the rate of 0.2-0.3% and requires ageing for at least 4 hours; often a practice of overnight ageing is followed. It is a good ice cream stabilizer since forms a weak gel that melts readily in the mouth giving no impression of gumminess. However, the so called ‘instant gelatin’ may not require such long ageing periods. The effectiveness of gelatin may be altered by interactions with other mix constituents at high temperatures. It is not suitable for vegetarians, and has now generally been replaced by other stabilizers.

The most important property of gelatin is its ability to form thermo-reversible gels. At a few percent in water, gelatin’s gel-melting temperature (<35 C) is below body temperature, which can provide gelatin products with a unique 'melt-in-mouth' quality. Gelatin’s most important attribute is its gel strength and, when determined by the standard method, is called the 'Bloom strength' or 'Bloom value.' Commercial products normally have a Bloom value that falls between 50 to 280.

i) Other hydrocolloids

Other hydrocolloids viz. agar agar, an extract from red algae and gums such as tragacanth, Arabic, karaya, etc have found use in sherbets and milk ices.

7.3.3 Milk proteins

With the exception of milk proteins and gelatin, all the other stabilizers are carbohydrates. Casein being a hydrocolloid in nature also causes a appreciable stabilizing effect in ice cream. Therefore, the levels of milk solids, and so milk protein, will determine the amount of stabilizer to beadded. Also, interactions of certain stabilizers such as alginate and k - carrageenan with casein are likely to have considerable impact on the overall stability of ice cream. Skim milk and its concentrated and dried forms are most common sources of milk proteins in ice cream mix, but protein products such as whey protein concentrates (WPC) and total milk protein (TMP) have also been used. High heat skim milk concentrate or powder have been known to give generally a superior texture ice cream.

7.4 Emulsifiers

Emulsifiers have been used in ice cream mix manufacture for many years. They are usually integrated with stabilizers in proprietary blends but their function and action differ remarkably from those of stabilizers. They can be classified as :

7.4.1 Hydrophobic :Examples include sorbitan esters,mono- and diglycerides of fatty acids, polyglycerol polyricinoleate, highly substituted sugars, polyglycerol esters, and propylene glycol esters.

7.4.2 Hydrophilic : Examples include ethoxylatedsorbitan esters, monoglyceride derivatives such as lactates, tartarates,citrates, low-substituted polyglycerol esters, and monosubstituted sugaresters.

7.4.3 Role of emulsifiers in ice cream

Emulsifiers are used to:

- Promote nucleation of fat during aging thus reducing aging time
- Improve the whipping ability of the mix due to their function at the air interface resulting in reduced air cell sizes and homogenous distribution of air in the ice cream.
- Produce a dry and stiff ice cream as they enhance fat destabilization, facilitating molding, fancy extrusion and sandwich manufacture.
- Increase resistance to shrinkage and rapid melt down due to a combination of the above two factors.
- Increase resistance to the development of coarse/icy texture, due to the effect of fat agglomerates, more numerous air bubbles, and thinner lamellae between adjacent air bubbles on the size and growth of ice crystals.
- Provide smooth texture in the finished product, due to fat structuring and interaction of fat agglomerates within the mouth during consumption.

6.3.1 HLB concept

Griffin (1949) forwarded hydrophilic-lipophilic balance concept. A specific emulsifier HLB is required to produce a particular type of emulsion. The HLB number indicates the percentage weight of the hydrophilic portion of an emulsifier molecule divided by 5. The HLB scale ranges from 0 to20.

Glycerol Mono Stearate (GMS) has got a HLB number of 3 whereas polysorbate 65 has got a HLB number of 13.

7.6.4 Properties of individual emulsifiers

a) Mono-/diglycerides

The most commonly used emulsifiers in ice cream manufacture are mono-/diglycerides (E471). Mono-/diglycerides are mixtures of monoglycerides and diglycerides. Mono- and diglycerides are surface active because the glycerol end of the molecule is hydrophilic and the fatty acid end is hydrophobic. Mono-/diglycerides are made by partially hydrolysing vegetable fats, such as soybean oil and palm oil. They normally contain 40-60% monoglyceride, together with diglyceride, and a small amount of triglyceride. Fully

saturated mono-/diglycerides that contain predominantly stearic and palmitic acids, such as glycerol monostearate, are often used for ice cream production and typically make up about 0.3% of the ice cream mix.

Materials with high monoglyceride content (> 90%) are available. These are difficult to disperse because they can become extremely viscous and form a gel in aqueous systems. However, this may be helpful in some applications. For example, the gelling properties have been exploited in the manufacture of very low fat ice cream.

b) Sorbitanesters

The sorbitan esters are similar to monoglycerides in that the sorbitan esers have a fatty acid molecule such as stearate or oleate attached to a sorbitol (glucose alcohol) molecule, whereas the mono glycerides have a fatty acid molecule attached to a glycerol molecule.To make the sorbitan esers water soluble polyoxyethylene groups are attached to the sorbitol molecule. Polysorbate 80, polyoxyethylene sorbitan monooleate is the most common of these sorbitan esters. Polysorbate 80 is a very active drying agent in the ice cream and is used in many commercial stabilizer/emulsifier blends. Although it is normally a component of stabilizer/ emulsifier blend, it can be added in pure form directly to mix flavour tank post homogenization and will become effective at enhancing dryness within a few minutes. Sorbitan esters of fatty acids, such as polyoxyethylene sorbitan monooleate (also known as polysorbate 80) are structurally similar to monoglycerides. These consist of a fatty acid attached to a sorbitol molecule instead of glycerol. Polyoxyethylene groups are also attached to the sorbitol molecule to make it water soluble. Polysorbate 80 can be used as an ice cream emulsifier, typically at concentrations of 0.1-0.2%.

c) Egg Yolk

Egg yolk, which contains several components with emulsifying properties, notably lecithin, is often used in ‘all-natural’, premium or homemade ice creams. Egg yolk has the approximate composition (by weight) of 50% water, 16% protein, 9% lecithin, 23% other fat, 0.3% carbohydrate and 1.7% minerals. Lecithin consists of phosphatides and phospholipids. Egg yolk is usually used in ice cream manufacture either as pasteurized fresh egg yolk, frozen sugared pasteurized egg yolk (which has about 10% sucrose added to protect it from damage during freezing) or as dehydrated egg yolk. Egg yolk solids are normally used at about 0.5-3%. High concentrations are only used for super- premium products, and cangive the ice cream an eggy flavour.

Stabilizers and emulsifiers are important ingredients in ice cream and they contribute to a great extent to the desired body and texture characteristics of ice cream and other frozen desserts. Generally a mixture of two or more emulsifiers/stabilizers is preferred to overcome drawbacks of individual compounds. Most of the commercial preparations are blends of emulsifiers and stabilizers which not only provide the convenience of use, but also make it possible to integrate stabilizers in a continuous emulsifier phase thereby facilitating dispersion of the stabilizer. The ice cream industry in India is growing at a

commendable rate so the demand of good quality stabilizers and emulsifiers is bound to go up. Intensive research is required to produce stabilizer emulsifier formulations to suit varying needs of the ice cream manufacturer.

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