Manufacturing high quality ice cream with high overrun

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Ice cream is a very common and loved dessert and snack around the world. Eating ice cream is perceived as a pleasure and a luxury treat. However, the full pleasure of eating ice cream requires a smooth and creamy product throughout the entire shelf-life. However, not only recipe and processing parameters influence the product quality as experienced by the consumer. Also during transportation and storage of the ice cream - from the factory via the shop to the consumer - a high risk of applying heat-shock with concomitant quality loss exists.

What is an ice cream?
Ice cream is a complex system of foam, containing a gas (air) dispersed as small cells in a partially frozen continuous phase. In the continuous phase fat is dispersed as an inner phase in an emulsion, where the milk solids and stabilizers are in a colloidal solution and sugar and salts form a true solution.

The importance of air in ice cream
Air is an important component in ice cream affecting the physical and sensory properties as well as the storage stability. Ice cream normally has around 100 % overrun meaning that the air makes up 50 % of the ice cream volume. The amount of air incorporated into the mix influences the sensory attributes of the ice cream. If a lower amount of air is applied, the resulting ice cream is dense, heavy and more cold eating. If a higher amount is used, the texture is lighter, creamier and more warm eating.

Producing ice cream with a high overrun
Production of ice cream with high overrun is an interesting tool for cost saving. However, the perceived quality by the consumer has to be kept in mind. The sensory attributes such as creaminess and smoothness as well as resistance to shrinkage and melting cannot be compromised as these properties are very closely linked to consumer preferences.

Creaminess as well as melting resistance is related to the distribution of air cells in the product. A more uniform air cell distribution in the ice cream results in a creamier and slower melting ice cream. Emulsifiers like mono- and diglycerides are well known for their positive influence in this respect.

The effects of emulsifiers
Production of ice cream with high overrun means, other things being equal, that the cell walls around the air cells are thinner and weaker. It is therefore at high risk production of very high overrun ice cream takes place. However, by choosing the right emulsifiers and stabilizers it is possible to manufacture an ice cream with high overrun which will still be perceived as a high quality ice cream.

Especially the emulsifier plays an important role: Emulsifiers are surface active ingredients due to their hydrophilic-lipophilic properties. Consequently, they place themselves in the interfacial layer between the fat/protein and water.

The main functionality of emulsifiers in ice is to destabilize the fat globule membrane covering the fat globules formed during homogenization of the ice cream mix. During ageing the proteins covering the fat globule are replaced by emulsifiers. Hereby agglomeration and partially coalescence of the fat globules is facilitated. This is important for the structure formation and air cell distribution formed during whipping and freezing. Further emulsifiers are important for the stability of the formed air cells i.e. the strength of the air cell walls.

In short terms the functionality of the emulsifier in ice cream is seen as:

- improved fat emulsification in the mix
- controlled fat agglomeration and coalescence
- facilitated air incorporation
- improved dryness on extrusion
- improved melting resistance
- improved heat-shock stability
- improved smoothness and creaminess

Types of emulsifiers
Mono- and diglycerides of fatty acids (E471) are the most commonly used emulsifier in ice cream. Mono- and diglycerides of
Fatty acids are produced by interesterification of glycerol and fat. The selection of fat determines the functional properties of the emulsifier.

The mono- and diglycerides can be further esterified with organic acids. For instance lactic acid is used for formation of E472b lactic acid esters of mono- and diglycerides of fatty acids, so called lactic acid esters.

Compared to mono-and diglycerides, lactic acid esters are more hydrophilic. Lactic acid esters are not commonly used in ice cream production. However, it has been found that it has a great influence on foam stability and texture when used in combination with mono- and diglycerides. This fact can be utilised in production of ice cream with high overrun.

The effect of stabilizers in an ice cream with high overrun
As always in ice cream the emulsifiers for high overrun ice cream are used together with stabilizers. The stabilizers are hydrated and dispersed in water reducing the amount of free water in the ice cream mix. The stabilizers bind the water by means of hydrogen bonds or trap the water in a three-dimensional network reducing the mobility of water resulting in an increased viscosity.

The main functions of the stabilizers are to:
- increase the mix viscosity
- prevent whey separation (syneresis)
- improve the whipping properties
- improve the texture
- prevent ice crystal growth (during storage)
- improve the melting resistance
- regulate sensory properties

The options when choosing stabilizers are far greater than in the case of emulsifiers. Most countries allow the use of a wide range of stabilizers. The most commonly used stabilizers in ice cream are:
- guar gum (E412)
- locust bean gum (E410)
- cellulose gum (E466)
- alginate (E401)
- carrageenan (E407).

Manufacturing ice cream with 150 - 185 % overrun
Palsgaard recently carried out a project with the aim of creating a solution for production of ice cream with overrun as high as 150 – 185 %. The quality in terms of sensory attributes, melt-down properties and storage stability should be comparable to standard ice cream. Ice creams with fat levels from 6 – 10 % were included in the trials. Vegetable fat was used as fat source and whey powder and/or skim milk powder was used as milk solid non fat. The use of whey powder also meant that the protein level was low in the some of the trials.

The ice cream was produced in Palsgaard’s pilot plant by means of a HTST unit combined with a continuous freezer. After hardening the ice creams were transferred to a storage freezer at -18°C. For evaluation of the storage stability heat-shock tests were carried out by increasing the temperature to -10°C for 4 days after which the ice creams were transferred back into the storage freezer.

Figure 1: 1-Monoglyceride (E471)

Figure 2: Lactic acid esters of mono- and diglycerides of fatty acids (E472b)

Figure 3. Guar gum, locust bean gum and alginate are often used as stabilizers in ice cream.
Sensory properties as well as melt-down properties were evaluated for samples without and with exposure to heat-shock. The melt-down properties were analysed at a controlled temperature of 25°C over 90 minutes.

**High shear benefits**

In order to obtain an ice cream with high overrun and a homogeneous air cell distribution it was necessary to apply higher shear in the freezer i.e. the dasher speed in the continuous freezer was increased. Higher shear also means higher degree of churning out in the freezer and hence stronger air cell walls and higher stability of the created ice cream structure. This was also confirmed in the melt-down and heat-shock tests. Figure 4 shows the melt down curves of 6% fat ice creams with 185% overrun. Results for ice cream stored at constant temperatures as well as heat-shocked ice cream are shown. For comparison also melting properties of a 6% fat ice cream with 100% overrun are included. Both ice creams are stabilized with Palsgaard® Extrulce 260. Palsgaard® Lactem 410 was further added to the high overrun ice cream.

From figure 4 it can be seen that only 4% if the 100% overrun ice cream stored at constant temperature had melted. If this ice cream was exposed to heat-shock 6% of the ice cream was melted during the 90 min. test period. The ice creams with 185% overrun were very stable and no drips from either of the ice creams were noticed during the melt-down tests. Shrinkage wasn’t observed in any of the samples.

**Using lactic acid esters**

The addition of the lactic acid ester of mono- and diglycerides to the recipe had a tremendous effect on both processing and melting as well as sensory qualities of the ice cream. Adding Lactem facilitates production of high overrun ice cream with an excellent and stable structure. Furthermore, it enhances the sensory properties by creating a creamy and full-bodied ice cream even in ice creams with 6% fat. Even high overrun ice cream exposed to heat-shock had a creamy and smooth mouthfeel without iciness. The high overrun ice creams were softer but still melted slower compared to a standard ice cream.

**Conclusion**

In conclusion it can be said that the ice cream factories now have a new cost cutting tool. By slightly modifying their existing recipes e.g. by using Palsgaard® Lactem 410 together with Palsgaard® Extrulce 260 they can produce an ice cream with high overrun while still keeping a creamy, smooth and full-bodied texture and mouthfeel. As the product also has excellent storage stability the ice cream still satisfies the consumers.

Should you like to know more about manufacturing ice cream with high overrun please contact Product Manager Hanne K. Ludvigsen at hkl@palsgaard.dk or Tel: +45 7682 7665.