

facts



Xanthan Gum
– a hydrocolloid in ice cream
for texture control and stabilisation

Jungbunzlauer

*From nature
to ingredients®*

Introduction

The estimated size of the worldwide ice cream market is around 15 billion litres. The market is distributed unevenly across the globe because the consumption pattern varies significantly between countries and regions. The highest consumption is found in the USA at around 26 litres per capita and year, for instance, while in Europe this rate is around 10 litres. (1)

Ice cream does not occur in nature. It is a created food item that is not consumed for its nutritional value but only for pleasure and as semi-luxury food. Ice cream is a product that is only consumed frozen – yet nobody wants it to be icy. If the consumer does not store the ice cream at a constant deep-freezing temperature, the very small and uniform ice crystals will grow into larger crystals and give the ice cream a coarse, icy structure (2). The consumer will then not consider the product to be edible anymore.

Ice cream is made up of a complex matrix of frozen foam, emulsified fat globules and suspended ice and lactose crystals. This matrix is highly susceptible to temperature variations. Reducing this sensitivity will help to maintain the quality of the ice cream during storage and thus improve the shelf life of the ice cream. A significant improvement can be achieved by using hydrocolloids to bind water and thereby control the growth of ice crystals. Additionally, hydrocolloids can be used to modify the melting properties and the mouthfeel of the ice cream.

According to a market analysis of hydrocolloids used in ice cream, 13% of approximately 14,000 total new ice cream launches (2012–2014) contain xanthan gum. (3) 75% of the newly launched ice creams were milk-based. Xanthan gum (XG) is often used in combination with guar gum (GG), locust bean gum (LBG) and carrageenan, but pectin, carboxymethylcellulose (CMC) and tara gum (TG) are also used as stabilising agents.

The hydrocolloids derive from different origins: XG is obtained by bio-fermentation of glucose with *Xanthomonas campestris*, GG is an extract of endosperm from guar beans growing on bushes mainly in India and Pakistan, and LBG – also known as carob – is an extract from the seeds of the carob tree. Carrageenan derives from red algae, sea weed or Irish moss. Many hydrocolloids are approved for use in food, registered with the following E-numbers: XG (E415), GG (E412), LBG (E410), CMC (E466), TG (417), pectin (E440) and carrageenan (E407) – often without a defined upper limit but according to *quantum satis*.



Functionality of hydrocolloids and their synergistic effects

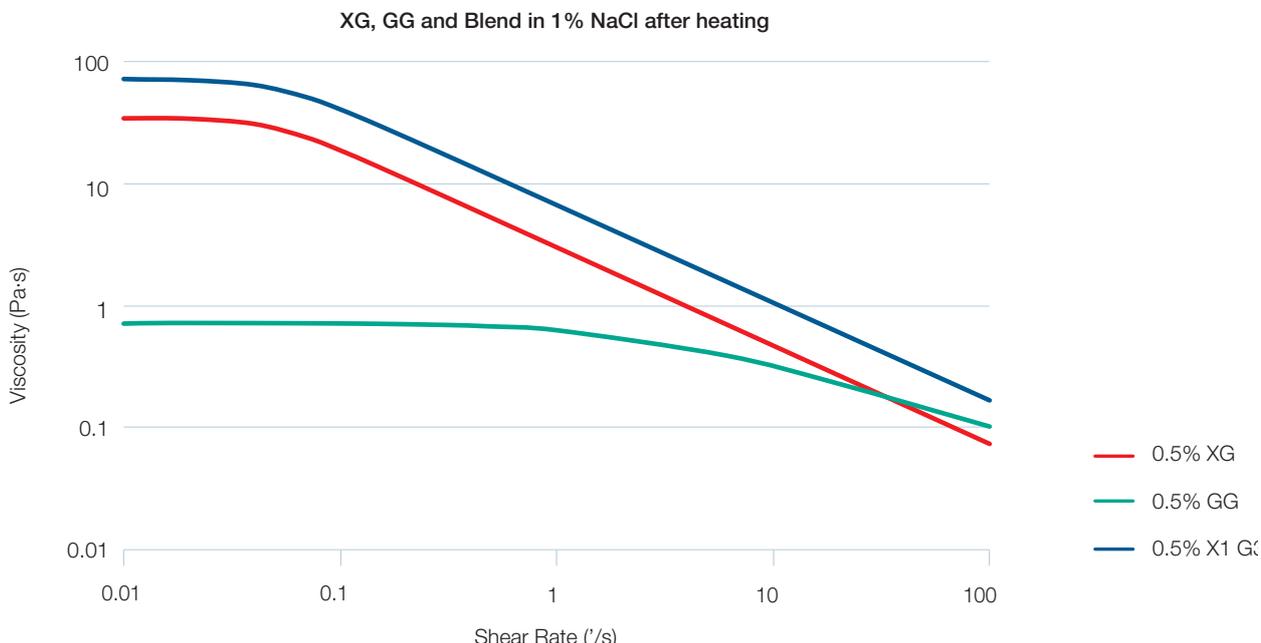
When properly hydrated, hydrocolloids increase the viscosity of aqueous solutions. As with the water binding capacities, the viscosities vary strongly between different hydrocolloids. The hydrocolloid solutions also show varying degrees of non-Newtonian behaviour and they are more or less shear thinning. In comparison to the galactomannans GG, LBG and TG, XG provides by far the highest viscosity at lower shear rates and the most extreme shear thinning. XG is thus the superior stabiliser, whereas galactomannans provide more thickness at high shear rates.

Combinations of Xanthan and one or more of the galactomannans are known to display synergistic behaviour, which means that the viscosity of the combination is higher than the sum of viscosities of the individual components. Theory explains that this is due to a special cross-linking of the molecules.

Xanthan gum has a glucose backbone and every second glucose-unit is substituted with a side chain of mannose-pyranosyl – glucuronic acid – acetyl-mannose. GG has a mannose backbone with a galactose roughly on every second monomer. LBG has the same backbone with a galactose on every fourth monomer. The cross-linking effects vary depending on the structure of the galactomannan. XG and GG combinations already provide higher viscosity when dissolved in cold water, whereas XG and LBG only react when the solutions are heated.

The synergistic effect between XG and GG is quite remarkable as it is visible in picture 1, which shows the shear curves for 0.5% of the pure products and a combination of both. At a shear rate of around 40/s, the viscosities of XG and GG are approximately equal. The viscosity of GG increases only slowly to around 1 Pa.s at low shear rates, whereas the viscosity of XG increases to 40 Pa.s. When using 0.5% of a blend containing 25% xanthan and 75% GG (X1 G3), the resulting shear curve is very comparable to xanthan gum, however with a significantly higher viscosity over the whole shear range.

Picture 1: The viscosity of xanthan, guar and a blend



The synergistic effects vary depending on the hydrocolloids used, the medium and production process (e.g. heating steps). They offer the developers of foods the opportunity to tailor the stability, thickness and mouthfeel of their products.

For ice cream production the manufacturers often use stabiliser systems, which are specifically tailored blends of different hydrocolloids, sometimes in combination with some emulsifiers. These combinations will obviously vary depending on whether the final products are dairy based ice cream, sorbet or lollies. Specifically for dairy based ice creams, the blends may also contain a small fraction of carrageenan. Carrageenan is very compatible with milk proteins and is able to develop a gel structure – even in low concentrations. Stabiliser blends are typically used in the range of 0.1–0.3% of the total ice cream formulation.

Table 1 shows a typical ice cream composition. The individual ingredients can vary widely. The total dry matter, however, is mostly maintained in a rather narrow range as its variation can easily make the texture hard, crumbly or too cold.

Table 1: A typical ice cream composition

Ingredient	%
Semi-skimmed milk	46.59
Cream	31.00
Sucrose	13.00
Skimmed milk powder	4.60
Dry glucose syrup	4.00
Emulsifier	0.40
Flavour	0.25
Stabiliser	0.16
Dry matter content	38.70



Ice cream process

The production of an ice cream starts with a concept for milk ice or sorbet and, importantly, with a recipe. Although there are many different varieties, the main ingredients for milk ice cream are 1) a blend of milk or cream and skimmed milk powder, 2) sugar and sweetener and 3) the special (blend of) stabiliser and/or emulsifier.

The ingredients are mixed and then the liquid mix is pasteurised through a heat treatment. The heat treatment also has a technological purpose by allowing the fat to melt and the hydrocolloids to fully hydrate and activate their (synergistic) performance. This step is followed by homogenisation and cooling after which the mix is left in a storage tank for ripening. This phase is important for the hydrocolloids to reach full viscosity development and for the maturing and crystallisation of the fat. (4)

One day after preparation and aging, the ice mix runs through the ice machine in which the mass is cooled down to around -5°C and some of the water freezes and forms ice crystals. This is also the process step where air is incorporated into the ice cream. The quantity of air incorporated into the ice cream can be finely controlled and is called the “overrun”. Besides adding volume to the ice cream, the air is very important for the final mouthfeel. A final overrun of 50–100% is common for standard ice creams.

In the ice cream machine, about 50% of the water will freeze and form ice crystals. The concentration of sugars and other substances in the aqueous phase will increase when a part of the water turns into ice, which will lead to the freezing point being reduced. The product leaving the extruder of the ice cream machine will be a smooth flowing product with three physical phases: solid crystals, liquid and gas. It has a marvellous, smooth, creamy and full bodied mouthfeel.

To preserve the consistency, the ice cream must quickly be frozen down to -40°C . It is kept at this temperature for two days for further ageing, before being transferred to a freezer at -20°C , where it can be stored for many months.

Ice cream heat shock test and structure analysis with scanning electron microscopy (SEM)

The problem with ice cream is that elevated temperatures may inflict irreversible damage to the delicate gas-liquid-solid structure. Consumers will not store the ice cream continuously at -20°C . It has to be taken from the freezer to be consumed and before any left-overs are returned to the freezer the temperature of the ice cream may have risen significantly. Even producers and retailers face problems continuously keeping ice cream at ideal storage conditions.

Hydrocolloids are being used to limit the negative effects of temperature swings on the quality of the ice cream. These effects can be measured by, for example, determining the change in size and frequency of the ice crystals and air bubbles in samples of ice creams using scanning electron microscopy (SEM). Different ice creams were prepared following one recipe where only the type and dosage of hydrocolloid was varied. Samples of the ice creams were stored at varying, but tightly controlled temperatures according to the protocol for the heat shock test in order to mimic a prolonged storage period with temperature swings.

A. Heat shock test

The ice cream was stored under cyclical temperature changes from -18°C (-0.4°F) to -10°C ($+14^{\circ}\text{F}$) within 12 hours for 14 days

B. SEM evaluation at -180°C (-292°F) mean values after evaluation of 10 pictures.

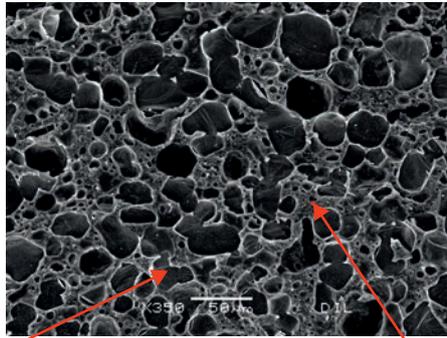
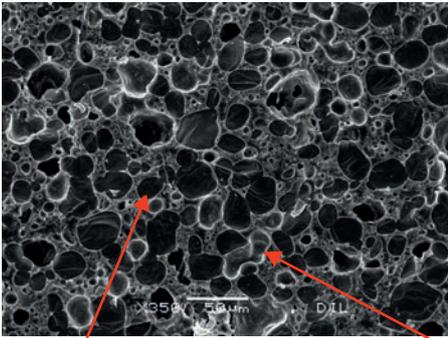
- a. Ice crystal size
- b. Ice crystal distribution
- c. Air bubble size
- d. Air bubble distribution



Pictures 2 and 3 show the microstructure of an ice cream sample by SEM. This sample was stabilised with a standard compound containing LBG, GG and carrageenan at a concentration of 0.16%.

Pictures 2: First day sample stored at -40°C test

Pictures 3: 14th day sample after heat shock



black spots: small air bubbles

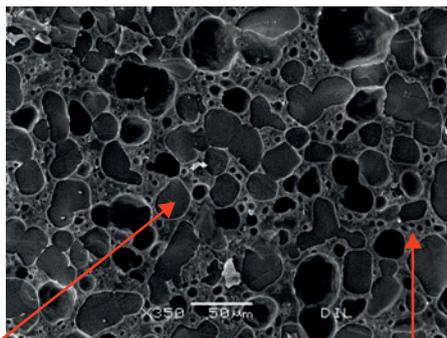
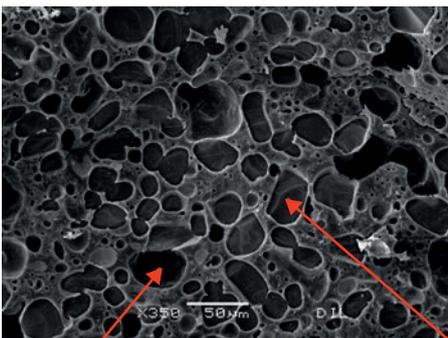
greyish spots: ice crystals

liquid concentrate

Pictures 4 and 5 show the microstructure of an ice cream sample by SEM. This sample was stabilised with a compound containing XG, LBG in a ratio of 25:75 and a concentration of 0.16%.

Pictures 4: First day sample stored at -40°C test

Pictures 5: 14th day sample after heat shock



black spots: small air bubbles

greyish spots: ice crystals

liquid concentrate

The SEM pictures clearly show that the solid particles and air bubbles are on average smaller than 50 µm in both fresh ice cream samples (day 1). The range of diameters after hardening confirms previous studies that suggested a mean ice crystal size of 45 to 50 µm after hardening (5). This size and distribution is very important for a nice and smooth mouthfeel as larger solid particles, e.g. ice or lactose crystals, will lead to sandiness or even a crunchy bite, which is absolutely undesirable and deemed to be poor quality. The stabiliser combination of XG and LBG at a concentration of 0.16% is able to control the particle size of the ice cream during the 14 days of stress test in a very similar manner as the benchmark containing LBG, GG, and carrageenan.

Both pictures look very similar. However, the single pictures are not representative for getting reliable values of the average ice crystal and the air bubble size and distribution.

To improve the statistical relevance, ten different pictures of each sample were analysed. The resulting volume distribution of ice crystals is shown in picture 5 for three different ice cream samples. The three samples differ in the hydrocolloids used:

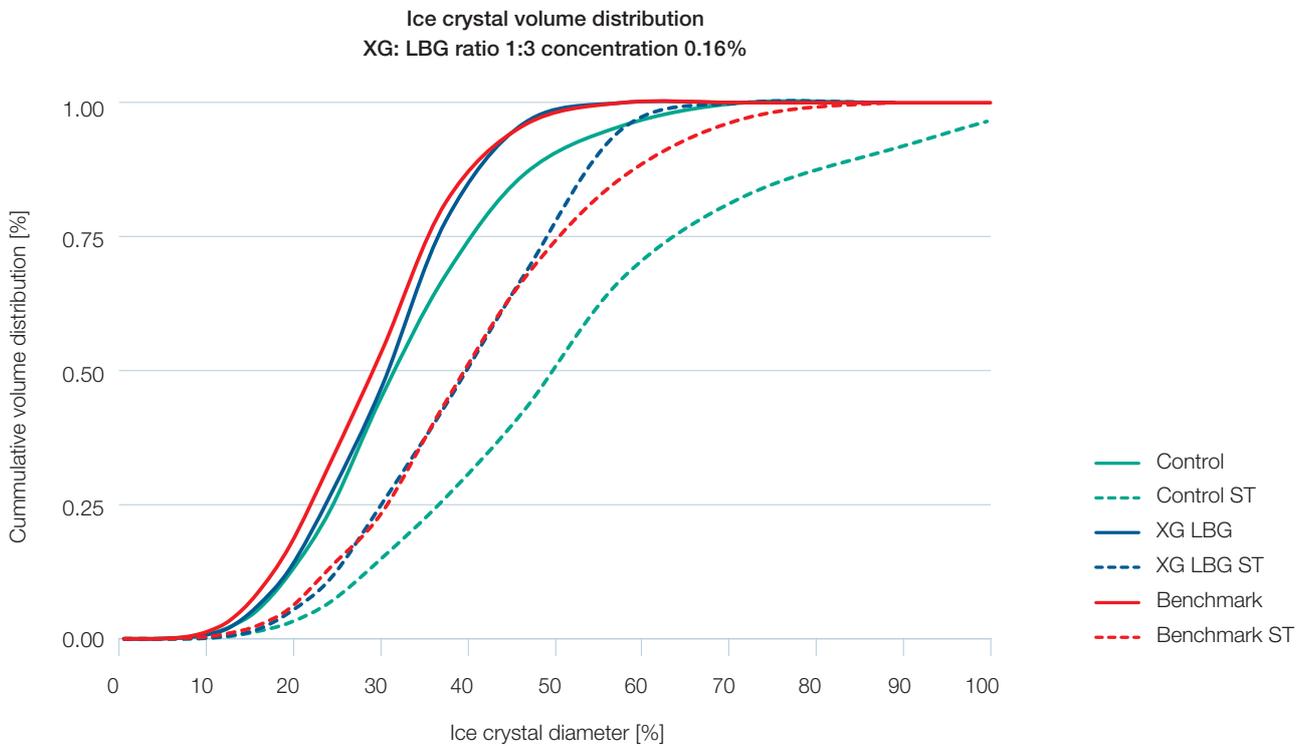
“Control”: no stabilisers

“XG-LBG”: 0.16% of a blend containing 25% XG and 75% LBG

“Benchmark”: 0.16% of a commercial stabiliser blend containing GG, LBG and carrageenan

The results are shown in picture 6. The solid lines represent the samples the first day after production and stored at -40°C. The dotted lines show the results for the samples after the 14 days of the heat shock test. The results clearly show that the control without stabiliser already starts off with the widest ice crystal volume distribution directly after production (day 1). After 14 days stress test, the combination of XG : LBG shows the narrowest ice crystal volume distribution, even a little better than the benchmark. The dotted line for the benchmark levels off at the higher crystal size, indicating that larger crystals were formed during the stress test.

Picture 6: Ice crystal diameter and volume distribution after analysing 10 SEM pictures of each sample



Summary

There are many hydrocolloids and stabilisers available on the market, each with different properties with regards to thickening, stabilising and water binding. They play an important role for the final haptic, mouthfeel and taste of the ice cream. If the stabiliser concentration is too high, the ice cream can become sticky with a slimy mouthfeel or it will not melt and will be less aromatic. If the concentration of stabiliser is too low, an increased number, in quantity and size, of ice crystals will be produced – leading to it becoming icier and melting faster.

There are some differences with the technological handling of the hydrocolloids. LBG must be heated in combination with XG, otherwise it will not provide the increased synergistic viscosity. The combination of XG with LBG leads to gelling in higher concentration of the ice mix, in the same way as carrageenan does.

This is not a negative effect for the ice cream production process. On the contrary: it shows the outstanding stabilising properties of these hydrocolloids because a gel will not separate. XG and LBG are most effective at retarding water recrystallisation in ice cream (6). Incompatibility between biopolymers can lead to local increase of the concentration of milk proteins at the ice crystals interface and probably exerting water-binding, which enhances the stabilising effect (6).

The decision is up to the manufacturer and to the consumer. Hydrocolloids can be added in order to stabilise and guarantee an acceptable shelf life in ice cream. Different hydrocolloids can be applied with slightly different properties. The single use of pure or compound systems – even with emulsifiers – is available. Ultimately, the taste, the cost profile, and the convenience in application will lead to the respective best combination of hydrocolloids as a stabiliser in ice cream for a manufacturer.

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Jungbunzlauer offers different grades of Xanthan Gum for food application as well as in pharma and personal care products.

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