Emulsifier Gel as a Cake Improver: A Review

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Abstract

Cake gels or alpha crystalline gels are cake improvers comprised of water, blend of different emulsifiers (Usually DMG, PGMS, SSL, and PGE) and solvents which are used primarily in production of eggless sponge cake. The key functionality of cake gel are that it boost cake volume through improved aeration of cake batter, increase cake viscosity and preventing coalescence of air bubble. It also improves the cake batter stability through increased batter viscosity along with the improved emulsification of oil and water in cake batter which imparts uniform and fine crumb structure to the end product. Cake gel is also added to improve softness of cake products and extend its shelf life.

Keywords: Emulsifiers, Emulsion, Cake, Cake Improver, cake gel, Alpha crystalline.

Introduction

Emulsifiers are important functional additives in trending food processing sector. Emulsifiers are surface active ingredients, which can emulsify and stabilize emulsions and perform many diverse roles in food product development. In the baking industry, the emulsifiers are also used for other effects. A sponge– cake batter with emulsifier can be whipped in a 1–stage process. The incorporation and stability of air bubbles are improved, resulting in a finer dispersion and giving a better cake quality. The most important factor affecting the function of an emulsifier is its physical state. The emulsifiers used for cake baking should be in the α-crystalline gel state to create a stabilizing film to cover the bubble surfaces. In the cake batter, all the α gel emulsifiers decrease the density, increasing the incorporation of air. Sucrose esters improved volume and tenderness of white layer cakes.
Alpha crystalline emulsifiers

Monoglycerides are polymorphic because they can exist in 4 crystalline forms- alpha, alpha prime, beta and beta prime. Powdered emulsifiers exist in the beta crystalline form- very stable and moderately functional. The beta crystal is the most firm and stable at low temperatures. Crystalline emulsifier molecules are oriented with the hydrocarbon chains in dense parallel layers. When heated in the presence of water, the hydrocarbons change from a solid to a liquid state with the water penetrating in between the polar groups of the bi-layers. On cooling the hydrocarbon chains crystallize, forming a sandwich structure of alternating surfactant and aqueous layers giving a α-crystalline gel phase. The alpha crystal form is known to be much more active and functional than the beta crystal. However this alpha gel is unstable and has a tendency to revert back to the beta crystalline form. Researchers have identified many reasons for the superior functionality of the alpha crystalline form. One major reason is that the liquid alpha crystalline form is more flexible than the rigid beta crystalline form and rearranges more easily during heating cycles. Thus alpha crystalline emulsifiers are able to form flexible and more protective films around the dispersed phase being it oil, air or water and preserve the emulsion.

At this stage it would be appropriate to clarify the term "alpha". Monoglycerides can have the fatty acid moiety at C-1, such monoglycerides are called 1-monoglyceride, or at C-2 when it is called 2-monoglyceride. A practice has also grown of calling the 1-monoglyceride as -monoglyceride and the 2-monoglyceride as -monoglyceride. This practice may be misleading as it relates to the positional isomerism of the emulsifier rather than the critical crystalline structure being discussed here.

A conventional and preferred method for the optimum utilization of Monoglycerides has been through hydration. Such GMS hydrates helped to provide both aeration and emulsification. However it was noted that on ageing these monoglycerides hydrates had reduced functionality. Whilst it was generally understood by bakers that hydrated monoglycerides were easier to use and distributed more evenly, it is now realized that upon hydration the mono-diglycerides were converted into the more active and functional alpha crystalline form. But since this crystal form is unstable it tends to change on storage to the more stable beta crystalline form which is less effective. The common practice of improving the functionality of powdered emulsifiers through hydration is a very imprecise way of forming the relatively unstable but more functional alpha crystalline form.

Techniques have now been developed to convert the emulsifier to the alpha crystalline form under controlled conditions and more vitally to stabilize the emulsifier in this state for periods of up to one year. These techniques are based on optimum selection of raw materials, processing techniques, use of transition inhibitors as well as optimum blending of emulsifiers to both optimize functionality as well as alpha stability.
The concept of blending emulsifiers for optimal results has been used commercially for some time now and a number of emulsifier blends are in use in the cake sector. To further this idea into the realm of alpha crystalline emulsifiers like monoglycerides, complimentary emulsifiers have to be selected which besides functional compatibility must also have the potential to preserve "alpha-stability". There are a class of emulsifiers are known as alpha tending which when hydrated convert to the alpha crystalline form. Some examples of alpha tending emulsifiers include DMG, PGMS, PGE, SSL and DATEM.

Propylene Glycol Monostearate (PGMS) is a type of Propylene Glycol monoester. This emulsifier is an ester where propylene glycol is combined with a fatty acid. The resultant product consists of both mono and di-esters. The mono ester component (e.g. PGMS) is a alpha tending emulsifier particularly functional as a aerating emulsifier in combination with monoglycerides. Purification through molecular distillation is critical in optimizing such a blend. Similarly, Polyglycerol esters (PGE) are emulsifiers in which the fatty acid is combined with a polyglycerol. The HLB of PGE depends on the degree of polymerization of the glycerol moiety and has wide acceptance and use in the European sweet goods industry. Based on this concept "alpha stable gels" comprising of monoglycerides and PGMS and/or PGE are now commercially available. They are complimenting in functionality as well as in mutual "alpha" stabilization and have unique potential particularly in cakes and other sweet goods.

An alpha stable gel made up of optimally blended alpha tending monoglycerides and PGE has a superior effect on a cake. Long chain fully saturated monoglycerides are known to have the best starch complexing ability. PGE is alpha tending and increases batter viscosity, thus contributing to aerated batter stability. PGE has dual capability to function as water in oil as well as oil in water emulsifier and in combination with monoglycerides can stabilize the oil-water cake batter emulsion at various stages of the baking cycle. The proportion of the monoglycerides and alpha tending emulsifier like PGE can be modified to suit high or low fat batters. Thus in low fat cakes, alpha tending emulsifiers can not only help in direct aeration of the aqueous stage but also in stabilizing the aqueous foam by forming an interfacial film around the entrapped air bubbles. In low fat batters alpha stable gels high in PGE can also help by giving a smooth feel and a thick batter viscosity typically seen in high fat batters.

**Stages in cake baking process**

1. A cake batter is a complex foam/emulsion. Incorporation of air through whipping combined with optimal distribution of air entrapped is very important. Cake quality not only depends on the aeration, but more importantly on the optimum number and size of the bubbles which define texture. Alpha crystalline emulsifiers are outstanding in their aeration potential. Traditionally cake batters have been mixed in a multistage process. Use of emulsifiers in a alpha crystalline configuration facilitates "all-in-one” or two stage mixing.
2. During the baking stage the batter is heated and the liquid emulsion phase is transformed, viscosity is changed, the air bubbles expand, moisture is lost and finally the internal and external cake structure is developed. The stability of the bubbles and uniform expansion helps optimize the volume. Development of the desirable emulsion stability and batter viscosity during the baking process is definitely influenced by the proper selection of alpha stable emulsifier gels.

3. Storage characteristics of a cake which is influenced by the staling cycle. The shelf life depends both on the well known starch retrogradation effect, but also on moisture retention and on optimum internal characteristics.

Emulsion & Emulsifiers

Oil and water are immiscible since the interaction results in high energy at the common surface. Through the physical action of mixing one can break up the oil into fine droplets which may be dispersed into the water phase to form a dispersion which may be called an emulsion. An emulsion is an unstable multiphase system containing at least two immiscible liquid phases. When the physical mixing action is stopped the oil droplets will coalesce and the oil and water will again separate into two different layers. To stabilize emulsion, the droplets of the disperse phase must be as small as possible and as widely distributed as possible in the continuous phase. Further the viscosity of the continuous phase must be high to retard coalescence.

Ultimately to prevent such coalescing of oil droplets and subsequent layer separation, certain chemicals may be used which are known as emulsifiers. Emulsifiers are made up of molecules that have a non-polar (fatty acid) end which carries no charge and has an affinity for oil and a polar (glycerol) end which carries a charge and has an affinity for water. Such molecules can situate itself at the interface between oil and water. The polar end will immerse itself in the aqueous phase and the non-polar end will immerse itself in the lipid phase and prevent coalescence of the oil droplets. This helps the two phases to stay intimately mixed and form a stable emulsion.

Emulsions may be characterized in two ways. In a first instance the oil droplets may be dispersed in the water leading to oil in water emulsion. If on the other hand the water droplets are dispersed in the oil, then we have what is known as water in oil emulsion. Foam is also a type of an emulsion where a gas is dispersed in a liquid phase or occasionally a solid phase. The affinity of emulsifiers for either oil or water is measured by the HLB scale. If the HLB of an emulsifier system is between 3-6, it has an oil affinity and such an emulsifier will optimally stabilize water in oil emulsion. On the other hand emulsifier with a HLB value of 9-18 has a preference for water and therefore will optimally stabilize a oil in water emulsion.

Functions of an emulsifier

The main functions of emulsifiers in the sweet goods sector of the baking industry are:
1. Optimizing distribution of oil in water dispersions and stabilizing the resultant emulsion.

2. Optimizing distribution of air and stabilizing the foam.

3. Optimizing internal characteristics to impart uniform and fine crumb structure.

4. Improving softness in the cake and extending shelf life.

5. Optimizing development of reduced fat products.

6. Optimizing use of liquid oils with low levels of Trans Fatty Acids.

As cake baking has become a more defined industrial activity, baking emulsifiers have become a very important class of ingredients in the manufacture of cakes and other sweet goods. In the early days bakers used eggs and lecithin as providers of natural emulsifiers mainly due to the presence of phospholipids that have surface-active properties.

In the early 1920s chemical emulsifiers made their first appearance in the form of mono-diglycerides. A mono-diglyceride is an ester produced when an acid combines with an alcohol. Specifically a mono-diglyceride is an ester which is formed when the fatty acid is a triglyceride fat which combines with a polyvalent alcohol - glycerol. Mono-diglycerides, the first chemical emulsifiers used in baking, contained about 40-50% of the monoglyceride - the component that is functional as an emulsifier. Subsequently distilled mono-glycerides were developed since such emulsifiers contained 90-95% of the functional monoglyceride. The introduction of monoglycerides helped the cake baker increase the amount of both fat and sugar in the batter and this resulted in rich, high ratio cakes with superior body and texture and excellent keeping qualities.

As the baking of cakes became more automated and the demands of the market called for cakes and sweet goods with a better quality and longer shelf life, emulsifier technologists developed a wide range of emulsifier products. To attend to these needs there has been progressing development of emulsifiers and some of the important ones are summarized below:

1. Long chained, saturated fatty acids have the best starch complexing ability. To increase shelf life of baked commodities Glyceryl Mono Stearate (GMS) was made by utilizing saturated long chain stearic acid. Such fatty acids were either derived from animal sources like lard or saturated through hydrogenation of vegetable oils. This saturated acid was then reacted with Glycerol to give GMS with superior anti staling properties.

2. It was observed that derivatives of monoglycerides with lipophilic tendencies had unique qualities to improve the quality of cake and other baked goods. Some of these products include PGMS and PGE. PGMS is often used in American sweet goods baking. Another derivative emulsifier is PGE, and it is very commonly used by European craft bakers but to date has been sparingly used by the North American sweet goods baker. Nevertheless it has substantial potential to improve American sweet goods as will be discussed below.
3. Commercial product development of emulsifiers for the baking industry has been predominantly based on the chemical properties of surfactants. In the ongoing search to develop new products, concepts have now been developed based on physical properties of emulsifiers, in particular the crystalline actions of emulsifiers.

**Specific Gravity**

Optimal blends of alpha tending emulsifiers may be made to suit specific needs. Thus a combination alpha stable gel of distilled monoglycerides and PGMS will optimize aeration and icing foam stability, prevent breakdown of water-oil emulsion and minimize syneresis particularly in frozen and refrigerated icings and fillings. A combination of monoglycerides and PGE may help improve appearance, sheen and most importantly mouth feel of low fat icing. This basic concept may help in the utilization of alpha stable emulsifiers in the development of superior icings, fillings and whipped toppings.

**Trans Fatty Acids**

Animal fats like lard/tallow tend to be saturated and thus solid at ordinary room temperature. Vegetable oils are usually liquid at room temperature due to the unsaturated carbon in the fatty acid component of the oil. Oil manufacturers solidify such liquid oils by the process of hydrogenation. Essentially this involves adding hydrogen across the double bond to create a saturated carbon bond. Despite the fact that a minor amount of trans fatty acids occur naturally in some foods, the commercial process of hydrogenation of unsaturated oils results in the formation of noticeable levels of trans fatty acids. There is now a growing awareness of the negative health effects of trans fatty acids. Consequently hydrogenated fats are now under review by various bodies including the FDA. This may result in labelling recommendations/ regulations requiring detection of the amount of trans fatty acid in baked products.

Consequently there is growing interest in the use of liquid oils in cakes, sweet goods and icings and whipped toppings.

The emulsifier needs to have solubility/dispersibility not only in the aqueous phase but also in oil. Monoglycerides in the beta crystalline form do not satisfy this criterion but alpha stable monoglycerides as well as alpha tending emulsifiers like DMG, PGMS and PGE would fit this requirement. Liquid oil tends to destabilize foams mainly protein based foams as found in cake batters. Emulsifiers in the alpha crystalline form can aerate as well as stabilize such foams.

With the use of liquid oils, the distribution and emulsification of liquid oil in water becomes critical in cake batters. Alpha tending emulsifiers like polyglycerol esters are known to enhance both the distribution of the liquid oil as well as the viscosity of the resultant emulsion. Alpha stable gels made with distilled monoglycerides are known to protect the dispersed liquid oil droplets by the formation of a flexible alpha crystalline film around the oil to preserve the traditional cake batter/foam. Low fat cakes/ sweet goods:
Fat reduced bakery foods have not achieved sufficient acceptance due to excessive deterioration in organoleptic properties. Alpha gels made with distilled saturated monoglycerides are excellent aerating agents for use in low fat sweet goods. Finer air distribution may result in better batter viscosity, giving a good quality product which is critical in low fat batters. A major drawback of low fat cakes is the reduced tenderness of the baked product. Use of liquid oil instead of plastic shortening in low fat cakes/sweet goods may assist in improving the tenderness. As described above the use of alpha stable emulsifier gels is of vital importance when using liquid oil because of their better aerating end emulsion stabilizing potential. Alpha crystalline gels may also have a role as structuring agents when used in reduced fat baked products Tortillas/Bagels.

**Shelf Life:**

The shelf life of sweet goods is dependent on

1. Control of starch retrogradation - Control of starch retrogradation is reflected by the amylose complexing potential. It has also been reported that hydrated alpha crystalline monoglycerides have the best steric fit with amylose. The inside of the amylose helix is lipophilic as are alpha stable monoglyceride gels.
2. Optimization of fat distribution and moisture retention - Alpha crystalline gels containing polyglycerol esters have the ability to optimize plasticity and moisture retention resulting in the products having extended shelf life.

**Conclusions**

It was concluded that the emulsifier gels in alpha crystalline form are more functionally active and has the ability to improve the aeration of cake batter and increased cake batter viscosity. It also improved emulsification of oil and water in cake batter which imparts uniform and fine crumb structure to the end product as well as added to improve softness of cake products and extend its shelf life.

**References**


