Current Issues in the Stabilization of Cultured Dairy Products

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ABSTRACT

The design of a successful stabilization system for a dairy gel system is dependent on several factors, including raw materials, existing processing systems, and end user requirements. Raw materials range from natural products that are subject to agricultural variations to customized ingredients that are made to consistent specifications. Processing systems range from well-established methods to the newest technology. End users vary from the consumer who is looking for retail products that are healthy, fresh, convenient, easy to prepare, and flavorful to a growing and profitable food service industry that emphasizes consistency, functionality, and extended product life.

In this commercial environment, stabilization systems are reviewed, and examples of applications within a specific set of conditions are given. The effect of natural grade carrageenan on the processing of sour cream is examined. The substitution of tara gum for locust bean gum in cream cheese is reviewed as a potential economic opportunity. The use of emulsifiers to control foam during the processing of cottage cheese dressing is discussed. An example of the effect of starch on gel texture is presented. Finally, a look at dairy emulsion stability required for freezing and thawing gives some insight as to how new end user demands require new approaches to product development.

INTRODUCTION

The stabilization of dairy products is becoming increasingly important as new commercial opportunities develop in the retail, food service, and industrial markets. Performance expectations are more specific, and product labeling is more demanding, making the design of stabilization systems more challenging. A review of some current issues in the production of cultured dairy products provides an appreciation for the commercial aspects of stabilization of dairy emulsions.

Historical Background

Dairy products are emulsions in which milk fat is the dispersed phase and serum is the continuous phase. The primary structure of the dairy emulsions that are found in dairy products with low pH is the acidic gel formed by milk proteins. Stabilizing ingredients interact with milk proteins, water, and other stabilizers to modify the gel structure and to immobilize water. With the exception of emulsifiers, ingredients in a typical stabilization system for cultured dairy products function in the serum or continuous phase. Product functionality depends on dispersibility, ions present, temperature, and interactions with proteins and other hydrocolloids.

During the acidification process, significant changes take place at the micellar level in dairy products. Direct addition of acid results in the precipitation of acid casein. However, slower acid development, such as that caused by bacterial action or hydrolysis of glucono-δ-lactone, results in the formation of a three-dimensional protein structure that traps moisture in a protein gel. The formation of this protein gel depends on temperature, protein source, and rate of acid production. The colloidal mechanism proposed by Banon and Hardy (1) is useful in understanding the structural effects in stabilized dairy products at low pH. At temperatures greater than 30°C, the proposed mechanism is a direct collision of casein micelles; the stability of these micelles has been lowered by the collapse of the “hairy” κ-CN surface layer. At temperatures less than 20°C, the proposed mechanism is solubilization of micellar casein, followed by reassociation of solubilized proteins on the surface of the remaining micelle, and eventually micelle aggregation to form the gel structure. When the caseins are solubilized, conditions are more favorable for hydrocolloid interactions with protein, leading to stronger gels and greater water immobilization. Because the culturing temperature of dairy products is typically 22 to 26°C, it is possible

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that both pathways are operating. Different pathways lead to different micro- and macrostructures that are represented in commercial products as variations in texture. Nodulation is associated with protein aggregation and certain starter cultures, and nodulation is present in cultured dairy products (6).

Sour Cream

Sour cream is a dairy product containing 18% fat and 28% total solids at a pH of about 4.6. The stabilizer systems for sour cream might include milk solids if they are designed to be complete systems, or they might be limited to thickening and gelation agents, such as starch, guar gum, carrageenan, and locust bean gum. Calcium-sequestering agents in the form of phosphate or citrate ions facilitate the interaction of these hydrocolloids with proteins and other agents. Sometimes emulsifiers are added to stabilize the milk fat, which is mostly solid at the normal storage temperatures of sour cream. Two current issues in the processing and performance of sour cream are fouling of the smoothing valve and stability to syneresis during freezing and thawing. These issues are the focus of further discussion.

Because of economic considerations, natural grade carrageenan has replaced refined carrageenan in many dairy applications. Although the functional polysaccharide portion of the carrageenan is not noticeably different, the higher cellulose level has created a processing problem for sour cream and other dairy products that must pass through a fine mesh smoothing device (3). This problem can be corrected by a return to refined carrageenan; however, economic factors suggest a better solution might be a reduction in mesh size to prevent fouling.

Prepared foods have become increasingly popular and have brought about the need for dairy products that can meet additional requirements. For example, development of the frozen chicken fajita dinner has led to the demand for a sour cream that can withstand the freezing and thawing required in the packaged dinner. Recognizing that typical sour cream stabilizer systems promote gel formation, ingredient modifications are needed to meet this new application. Methylcellulose is a good choice in this application because it has the combined properties of cold hydration and hot gelation. Methylcellulose can immobilize water at cold temperatures and thicken at elevated temperatures to prevent excessive melt. A suitable nonfat sour cream can be produced by replacing carrageenan and locust bean gum in the stabilization system with methylcellulose and starch. This product can be filled in small packets, frozen, thawed, and then squeezed onto a heated food without water separation or excessive melting.

Cream Cheese

Cream cheese is a dairy emulsion containing 33% fat and 45% total solids at a pH of about 4.7 to 5.0. Its higher level of milk solids provides sufficient protein to create a firm gel at low pH. In this gel, the primary function of the stabilizer system is to immobilize water and help smooth the texture. The most common ingredients are locust bean gum, xanthan gum, and guar gum. Small amounts of carrageenan can be used for moisture control, and starch is sometimes used in low fat systems to build body and replace fat.

Guar gum, tara gum, and locust bean gum are galactomannans that differ in the ratio of galactose to mannose content. The ratio for guar gum is 1:2, for tara gum is 1:3, and for locust bean gum is 1:4. In reality, these polysaccharides exist as long mannose chains with sections of galactose branches. A lower ratio of galactose to mannose provides a greater probability of finding longer sections of the chain that are free from branching. These linear sections can align and interact with proteins and other hydrocolloids to build viscosity and body. Tara gum can exhibit behavior similar to that of guar gum or locust bean gum, depending on the distribution of branching along the chain.

As an agricultural product, locust bean gum is subject to crop fluctuations. In 1995, a crop failure created higher demand and caused prices to increase from about $7.72/kg to as much as $37.48/kg. Cream cheese was greatly affected because locust bean gum is a key stabilizing ingredient in this product, and the search for a suitable replacement began in earnest. Previous experience indicated that guar gum cannot directly replace locust bean gum because of high processing viscosity, soft body, and undesirable texture. Xanthan gum is a technically viable replacement but has a moderately high cost compared with that of other alternatives. Tara gum has been identified by several ingredient suppliers as a commercial replacement for locust bean gum that is worthy of further investigation. Because the incremental viscosity after heating and cooling is greater for locust bean gum than for guar gum, a decision on the replacement of locust bean gum by tara gum can be made from comparisons of viscosity after heating and cooling a standard cream cheese formula containing commercially available locust bean gum and tara gums in a typical stabilizer system.

Cottage Cheese Dressing

Incorporation of air in dairy emulsions can be a processing and quality problem. When foam is to be avoided or minimized, as in cottage cheese dressing, there are several approaches to a solution. It is always best to eliminate the sources of air incorporation, which are often joints, pumps, homogenizers, agitators, unbalanced flow, and splashing. Defoamers have limited effectiveness and are generally expensive. Certain emulsifiers added to the stabilizer system can be effective. The emulsifiers act as surfactants, which displace protein at the air-serum interface and create an unstable monolayer with respect to bubble collapse (2). For example, when polysorbate 80 is added to cottage cheese dressing, the amount of foaming is significantly reduced.

MATERIALS AND METHODS

Skim Milk Viscosity

Guar gum, tara gum, and locust bean gum were evaluated at 0.2% in skim milk. The ingredients were blended, heated with agitation to 75°C, and quickly cooled to 4°C. The viscosity of the resulting mixture was measured quiescently with a viscometer (Brookfield RVD; Brookfield Engineering Laboratories, Stoughton, MA) at 75°C, using spindle #2 at 100 rpm and after cooling to 4°C using t-spindle B at 50 rpm.

Cream Cheese Viscosity

Tara gum and locust bean gum were also evaluated at 0.2% in a typical cream cheese formula of 33% fat and 45% total solids. The ingredients were blended, heated to 75°C with agitation, then homogenized at 13.8 MPa, and finally cooled to 4°C. A two-stage homogenizer (APV model 15MR-8TBA; APV Gaulin, Wilmington, MA) was used; the first stage was set at 10.3 MPa, and the second stage was set at 3.5 MPa. The viscosity was measured at 75°C with a Brookfield RVD viscometer using RVF spindle #3 at 20 rpm and at 4°C using t-spindle D at 4 rpm.

Starch Gel Strength and Viscosity

Thermtex® and N-Lite D® (National Starch and Chemical Company, Bridgewater, NJ) were first combined in 10% increments, ranging from 0 to 100% each, and then dispersed at 10% total solids in water. The dispersion was heated to 82°C with agitation, held 20 min, homogenized at 13.8 MPa, and cooled to 65 and 4°C. A two-stage homogenizer (APV model 15MR-8TBA; APV Gaulin) was used; the first stage was set at 10.3 MPa, and the second stage was set at 3.5 MPa. The viscosity was measured at 65°C with a Brookfield LVT viscometer using spindle #2 at 20 rpm. The gel strength was measured at 4°C using a cone penetrometer with a 60° cone.

RESULTS AND DISCUSSION

Sour Cream

To render the texture of acidic gel commercially acceptable as sour cream, the process of smoothing is introduced after the coagulum is broken. Although several techniques have been used to smooth the texture, one of the most popular is use of a single-service homogenization valve. This valve can be described as a tightly woven stainless steel plug that creates a mild shear force by flow diversion when product is pumped through it. This device, commonly termed a smoothing plug, can be readily fouled by the relatively small quantities of insoluble cellulose fiber that are present in natural grade carrageenan and certain seed gums. Customers reported the need to replace the smoothing plug after processing about

TABLE 1. Viscosity of skim milk containing guar gum, tara gum, or locust bean gum after heating to 75°C and after heating to 75°C, followed by cooling to 4°C.[1,2]

	Locust bean		Tara		Guar	
Temperature	Hot	Cooled	Hot	Cooled	Hot	Cooled
(°C)	(cP)					
75	156	1752	200	1912	192	1880
79	208	1736	236	2240	208	1696
82	172	1616	245	2432	224	1800
85	192	2080	268	2400	220	1832

[1]All gum concentrations at 2%.

[2]All samples cooled to 4°C.

TABLE 2. Viscosity of a model cream cheese system containing commercial samples of tara gum, after heating to 75°C and after heating to 75°C, followed by homogenization and cooling to 4°C.

Gum[1]	Viscosity		Ratio of hot to cold viscosities
	Hot	Cold	
	(cP)		
Locust bean	1730	173,000	100
Tara 1	1975	183,000	93
Tara 2	1785	131,500	74
Tara 3	2195	130,000	59
Tara 4	1945	149,000	77
Tara 5	1980	196,000	99
Tara 6	2630	152,000	58
Tara 7	1755	165,000	94
Tara 8	1780	217,000	122

[1] All gum concentrations at 2%.

1900 L of mix as a significant processing problem. The nature of this problem prevented laboratory experimentation, so the solutions were generated during commercial processing.

Fouling can be corrected by reducing the mesh size of natural grade carrageenan, reverting to refined carrageenan, or changing the design of the smoothing device to accommodate the increased amount of insoluble material. Reduction of carrageenan mesh size is the most economical and straightforward solution and is applicable for certain seed gums such as guar and locust bean gum. Substitution of finer mesh (minimum of 75% passage through a 75-μm screen), natural grade carrageenan and guar gum in a commercial sour cream stabilizer eliminated the need to replace the smoothing plug after processing 1900 L of mix.

Cream Cheese

The viscosity of guar gum and tara gum increase gradually as a water solution of these gums is heated (4). Locust bean gum, however, is not fully functional until a temperature of about 80 to 85°C, and a water dispersion begins to thicken at this temperature. All three gums show increased water viscosity when cooled after heating, but the effect is greater for locust bean gum. The interaction with milk proteins is demonstrated in Table 1 when stabilizer systems containing these gums were dispersed in skim milk, heated to a typical process temperature, and cooled to a typical package temperature. The higher viscosity at 75°C indicates that tara gum, like guar gum, is functional at a lower temperature than is locust bean gum. The difference in viscosity at 75 and 4°C is related to the gel formation characteristics of the gums.

In a system containing 33% fat and 45% total solids, which is characteristic of cream cheese, the effects on viscosities by eight commercial tara samples varied considerably (Table 2). Product performance paralleled the gel formation characteristic of the gum and correlated best to the viscosity ratio of 40 to 75°C. Tara gum samples 1, 5, 7, and 8 produced body and textural results similar to the locust bean control, and their viscosity ratios of 40 to 75°C were closest to that of the locust bean gum. Sample 8 exhibited superior performance by this comparison, but, on further investigation, this sample was found to contain about 5% κ-carrageenan by weight, demonstrating a synergistic effect of κ-carrageenan on the gelling properties of tara gum.

Starch Gel Texture

Starch and its derivatives are increasingly popular ingredients in dairy systems because of their cost and availability. Much is known about the relationship of their functionality to structural modifications (5). The selection of starch ingredients as fat replacers in dairy products can be effectively done in a model system using commercially simulated processing conditions. Modified waxy maize starches, such as Thermtex®, yield translucent water dispersions that are thick and stringy. Modified tapioca maltodextrins, such as N-Lite D®, yield opaque water gels that are short and brittle. For example, as illustrated in Table 3, the optimum combination for a nonfat cream cheese that is vat pasteurized might be 70% modified waxy maise starch and 30% modified tapioca maltodextrin to obtain the firmest body, 70 mm; the

TABLE 3. Viscosity of combinations of modified waxy maize starch and modified tapioca maltodextrin (10% aqueous solutions) after heating to 82°C, followed by homogenization at 10.3 MPa and cooling to 65°C and gel strength after cooling to 4°C.

Starch type[1]		Hot viscosity	Cold gel strength
Thermtex®	N-Lite D®		
(%)		(cP)	(mm)
0	100	3	110
10	90	4	114
20	80	6	112
30	70	10	110
40	60	39	90
50	50	282	74
60	40	515	90
70	30	6510	70
80	20	19,600	84
90	10	37,750	113

[1] Thermtex®, a modified waxy maize starch, and N-Lite D®, a modified tapioca maltodextrin, were obtained from National Starch and Chemical Company (Bridgewater, NJ).

optimum combination for HTST pasteurization of a nonfat sour cream might be 50% modified waxy maise and 50% modified tapioca maltodextrin to maintain a low processing viscosity of 282 cP.

CONCLUSIONS

Stabilization of commercial sour cream is focused on strengthening the gel and immobilizing water. Conditions of acidic gel formation affect the contribution of the stabilizer. If changes in stabilizer ingredients create operational problems that cannot be duplicated in the laboratory, they must be evaluated under commercial conditions. A new performance requirement, such as stability during freezing and thawing, requires modifications to the typical sour cream stabilizer system to control the balance between gelation and thickening as well as the water mobility at the desired pH and temperature.

Stabilization of commercial cream cheese is focused on smoothing the texture and immobilizing water. The protein level is sufficient to create a strong gel. Ingredient substitution can be evaluated in a model system that simulates normal production conditions to enable good decisions to be made for commercial applications. Direct replacement of locust bean gum by tara gum in cream cheese does not appear to be feasible, but synergistic effects with carrageenan can improve the replacement. Cost fluctuations of ingredients require replacement options to be reversible. Evaluation of starch ingredients under commercial processing conditions can facilitate the textural design of low fat dairy products. The use of defoaming emulsifiers is effective in controlling the air incorporation during processing of cultured dairy products, but the best solution is the elimination of the source of air incorporation.

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