The Production of Specialty Milk Fat Ingredients[1]

K. E. KAYLEGIAN
Wisconsin Center for Dairy Research,
Madison 53706

ABSTRACT

Butter has a very desirable flavor and is perceived by consumers as a high quality, natural product. However, its use in foods is sometimes limited by its functional performance. Milk fat is traditionally supplied to the food industry as butter or anhydrous milk fat, which may not be the forms best suited to some applications. The functional requirements of fats vary greatly depending on the application. For example, conventional butter is too firm to be spreadable when used directly from the refrigerator, but, for pastry applications, conventional butter is too soft. The functional properties of milk fat are easily modified by the use of fractionation, selective blending, and appropriate texturization to produce ingredients that are tailored to specific applications. Dry crystallization of milk fat is a simple physical process that separates milk fat into fractions that have different physical and chemical properties. Milk fat fractions can be blended with other fractions, intact milk fat, and other fats to produce an ingredient with the right melting profile. The fat blend is then combined with skim milk and other ingredients (e.g., emulsifiers and salt) and recrystallized under controlled conditions. This approach is illustrated for the manufacture of milk fat ingredients that are suitable for pastry, chocolate, and other applications.
(**Key words**: milk fat, milk fat fractions, butter)

Abbreviation key: **AMF** = anhydrous milk fat.

INTRODUCTION

Butter contributes desirable flavor, appearance, and textural properties to foods. Butter flavor is inherently desirable to humans as is confirmed by the large number of butter-flavored products on the market. Butter has a premium image and is considered a good, wholesome food by most people. However, there are health concerns regarding the amount of fat and cholesterol in butter. As part of a healthy diet, butter can contribute substantially to the flavor and quality of foods. The focus of this paper is on the use of milk fat as a functional food ingredient, not as a table spread or specific dietary food.

Milk fat is found in many dairy foods, all of which have different levels of fat, water, and other potentially functional components. Traditional milk fat sources include fluid milk (1%, 2%, whole, and buttermilk), cream (light, heavy, and concentrated), dried products (milk, cream, butter, buttermilk, milk, and chocolate crumb), butter (salted and unsalted), anhydrous milk fat (**AMF**), and butter oil. The milk fat content in these products ranges from 1 to 99.8%. The functional performance of these ingredients often depends on the total fat content and the presence of other functional components (e.g., proteins and phospholipids). The native properties of milk fat become more dominant in ingredients that contain higher amounts of fat, such as butter and AMF. The native chemical, physical, and functional properties of milk fat vary naturally (5).

Another category of milk fat ingredients is what I like to characterize as specialty milk fat ingredients, which are tailored for specific end uses. These ingredients are based on milk fat fractions and are generally 80 to 100% milk fat. Rather than attempting to use traditional dairy ingredients for all food applications, specialty ingredients are designed to optimize the functional characteristics that are desirable and important to a given application. The most common changes made to milkfat are melting profile and melting point, plasticity, and total fat content. Technologies used to make these modifications are fractionation, blending, and texturizing. This approach to the manufacture of speciality milk fat ingredients has been used in Europe since the 1970s and in New Zealand since the late 1980s and is now available in the United States.

MANUFACTURE OF MILK FAT INGREDIENTS

Specialty milk fat ingredients can be manufactured using five basic steps: 1) fractionate milk fat to create blending stocks with a range of physical and chemical properties, 2) blend milk fat fractions and intact milk fat to target specifications, 3) add other functional

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ingredients (optional; aqueous phase, salt, and emulsifiers), 4) texturize mixture to proper finished form (optional), and 5) package (5).

The target specifications and characteristics of the finished product depend greatly on the final application. Therefore, it helps to understand as much as possible about the final application and requirements of the ingredient to use the least amount of processing necessary to obtain the best performance from the ingredient. For example, a chocolate manufacturer does not want water in the chocolate, and the milk fat is melted when it is added to the chocolate. Therefore, an aqueous phase is not needed, and the product does not need to be texturized. However, a pastry manufacturer needs water for leavening in the finished product and also requires plasticity of fats for rolling. Texturization of bakery ingredients is necessary to stabilize the emulsion and plastic properties. The desirable functional attributes for selected applications is discussed later.

Milk fat fractionation is defined as the separation of whole milk fat into components, or fractions, having different physical and chemical properties. Anhydrous milk fat is the raw material for fractions because it is 99.8% fat. The presence of water, proteins, and other materials interferes with the crystallization process. The most common method used to fractionate milk fat commercially is dry crystallization with either vacuum or pressure filtration. Other methods are available (3, 5, 6), but none are currently used commercially to fractionate milk fat.

Dry crystallization is a simple, physical process that is used to separate milk fat triglycerides based on their melting points. First, AMF is placed in a stainless steel, jacketed tank with an agitator. The AMF is heated to 60°C to remove all prior crystals, then cooled slowly under controlled conditions, and allowed to crystallize. Numerous variables can be manipulated during milk fat fractionation, which can greatly affect the properties of the fractions. Some of these variables include fractionation temperature, cooling rate, and agitation rate. Milk fat crystallization is slow by nature, and each crystallization step can take anywhere from 6 to 36 h. At the end of the crystallization process, the slurry consists of solid milk fat crystals suspended in liquid milk fat. This slurry is then pumped to a vacuum or pressure filter where the solid and liquid fractions are separated.

At the end of each fractionation step there are two fractions, one solid and one liquid. These fractions can be remelted and refractionated, and it is most common to refractionate the liquid fraction. The liquid fraction is reheated and crystallized to a temperature that is successively lower than the first step. This process can be repeated. A three-step fractionation seems to be the most commercially viable, although seven steps have been reported in the literature (5). For a single-step fractionation, there are two fractions, one liquid and one solid. For a three-step fractionation, there can be six fractions, three liquid and three solid, or four fractions (three solid and one liquid) if all of the liquid fraction from steps 1 and 2 are refractionated.

The properties of the fractions are different depending on how they are fractionated. For example, fractions have a different melting profile depending on whether the solid fraction is from a one-step process or whether the fraction was the second solid fraction from a multiple-step process, even though both fractions were separated at the same temperature. Figures 1 and 2 illustrate melting profiles for milk fat fractions obtained by single- and multiple-step fractionation, respectively. Figure 1 represents four separate batches of milk fat that were fractionated at four different temperatures. The melting profiles all exhibit the same basic shape but show a progressive softening from the fractions separated at 34 to 20°C. Figure 2 represents seven fractions that were obtained from one batch of milk fat that had been fractionated at temperatures from 34 to 13°C. The melting profiles for these fractions show more distinctive differences in the melting behavior than fractions obtained by single-step fractionation. These curves illustrate the advantage of using different fractionation protocols to change the melting behavior of milk fat ingredients.

Fat ingredients are often chosen or specified based on their melting characteristics. Milk fat fractions are reported in the literature as high melting or low melting but lack a standardized definition of these terms. Kaylegian and Lindsay (5) developed a framework of definitions for the discussion of milk fat fractions. (5). Figure 3 shows solid fat content profiles for several categories of milk fat fractions as defined by Kaylegian and Lindsay (5). Very high melting fractions melt above 45°C (113°F), high melting fractions melt between 35°C (95°F) and 45°C (113°F), middle melting fractions melt between 25°C (77°F) and 35°C (95°F), low melting fractions melt between 10°C (50°F) and 25°C (77°F), and very low melting fractions melt below 10°C (50°F).

The fat phase of a milk fat ingredient is made by choosing and blending different milk fat fractions and whole milk fat until the target specifications are met. So far, the discussion has concentrated on meeting melting profile specifications (e.g., dropping point and solid fat content) as the primary specification for

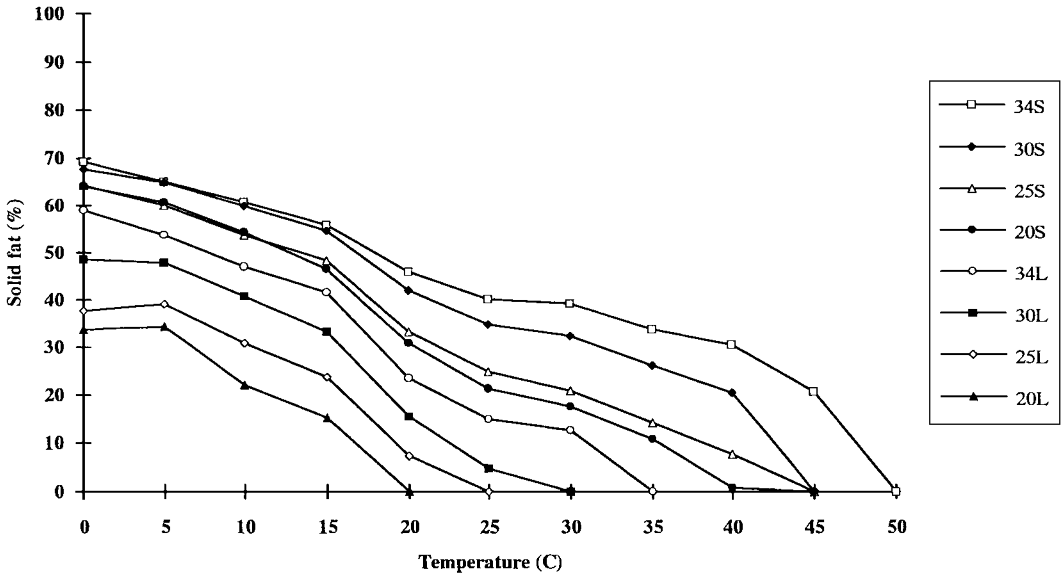

Figure 1. Solid fat content profiles of milk fat fractions obtained by single-step fractionation of melted milk fat (5). 34S = solid fraction at 34°C, 30S = solid fraction at 30°C, 25S = solid fraction at 25°C, 20S = solid fraction at 20°C, 34L = liquid fraction at 34°C, 30L = liquid fraction at 30°C, 25L = liquid fraction at 25°C, and 20L = liquid fraction at 20°C.

functional performance. The aqueous phase is generally skim milk, buttermilk, or nonfat dry milk and water. Optional functional ingredients include salt, flavor, color, and emulsifiers. All of the fat ingredients must be mixed together and fully melted, and all of the aqueous phase ingredients need to be fully mixed and dissolved before the two phases are emulsified. Care should also be taken to add optional ingredients to the correct phase (e.g., salt to the water phase and emulsifiers to the fat phase). When the fat phase is fully melted, the water phase is added with sufficient stirring to homogenize the mixture but not aerate it. The ratio of fat to water phase in the finished product depends on the final application.

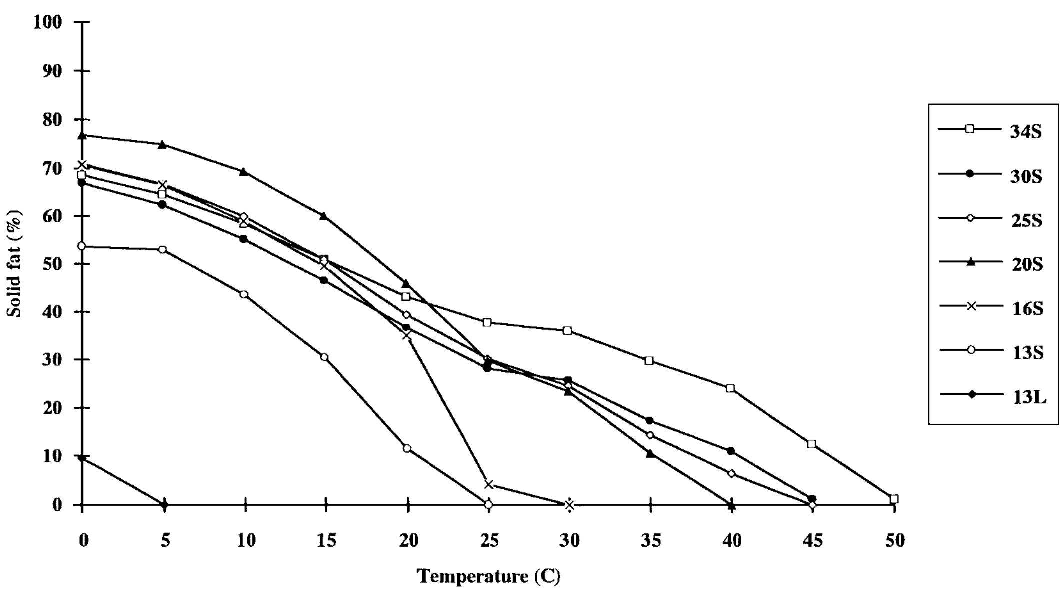

Figure 2. Solid fat content profiles of milk fat fractions obtained by multiple-step fractionation of melted milk fat (5). 34S = solid fraction at 34°C, 30S = solid fraction at 30°C, 25S = solid fraction at 25°C, 20S = solid fraction at 20°C, 16S = solid fraction at 16°C, 13S = solid fraction at 13°C, and 13L = liquid fraction at 13°C.

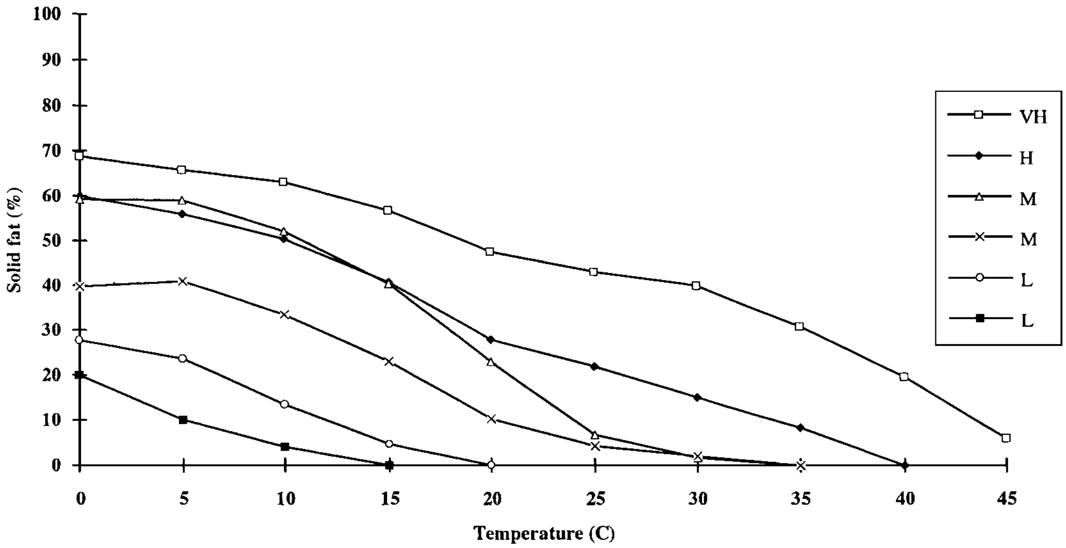

Figure 3. Solid fat content profiles for milk fat fractions. VH = very high melting, H = high melting, M = middle melting, and L = low melting (two different samples for M and L).

If the finished product is to be anhydrous, it can be packaged just after fractionation or blending. If the product is to have a water phase, the emulsion needs to be recrystallized using a texturizer. Texturization is necessary for emulsified products and for plastic anhydrous products. The texturization process involves rapid crystallization of the product with scraped-surface heat exchangers and pin working machines. Unlike fractionation, which is a gentle crystallization that takes hours, crystallization processes used during texturization occur in a matter of minutes. Such a process is used commercially for recombined butter and margarines and is known by trade names such as Votator, Perfector, and Kombinator. Important processing conditions to monitor include throughput, cooling temperatures, shear, mechanical work, and resting periods. These processing conditions affect the crystallization, melting, and plastic properties of the finished product. The effects of various processing parameters on the production of milk fat ingredients are currently being studied.

CONSIDERATIONS FOR SELECTING MILK FAT INGREDIENTS

Milk fat ingredients can be used in many foods as primary or minor ingredients, and the function of the fat can vary greatly. Different applications have different requirements for fats, so it is best to tailor the milk fat ingredient to meet the needs of application.

I find that it is most helpful to determine, first, which attributes are most important to the finished product and then to work backward to find the best ingredient. Considerations in creating or selecting milk fat ingredients include the type of product, desired attributes of the product, formula and process demands, and market and distribution demands. A milk fat ingredient designed for pastries will not be the best ingredient for use in cakes, chocolate, or table spreads. Each finished product or application has its own characteristic attributes (e.g., flavor, texture, and structure) and unique formula and processing demands.

For example, the addition of 10% milk fat to a dark chocolate has a much different effect than the same addition to milk chocolate, which already contains some milk fat that contributes to a softer texture. Puff

TABLE 1. Functional attributes of milk fat ingredients (5).

During processing	Finished product
Structure	Flavor
Firmness	Texture
Plasticity	Mouthfeel
Lubrication	Appearance
Aeration	Structure
Shortening	Spreadability
Layering	Firmness
Viscosity	Antibloom properties
Flow	
Solution and dispersion	
Heat transfer	
Emulsification	

pastries and croissants are two pastries that fall into the same category (i.e., laminated), but their optimal characteristics and eating qualities are quite different. Puff pastry is a flakier and crispier product than the softer, yeast-leavened croissant, and there are different roll-in fats available for each application (1, 2). The processing demands of a small artisan shop, where products are made to be consumed in a matter of hours or days, are different from demands of large, automated factories producing products with an expected product shelf-life of several months. There are many factors that affect product manufacture and quality and influence the functional performance that is required from the fat ingredients. Once again, it helps to understand as much as possible about the final application, including all stages of manufacture, distribution, and storage.

USE OF MILK FAT INGREDIENTS IN FOODS

Fat ingredients contribute a range of functional properties during processing and to the finished product (Table 1). These functional attributes are described in more detail elsewhere (4, 5). Some attributes are only important for selected applications, but an attribute such as flavor is important for most applications. For example, spreadability is important for table spreads but is not relevant for chocolate applications. Structure formation is also very specific to the application. The role of fat in the structure formation of laminated pastries and cookies is to disrupt the three-dimensional formation of gluten; however, the mechanism varies. In pastries, the layers of dough are separated by layers of fat that must

TABLE 2. The use of milk fat ingredients in foods.

Application	Desired functional attributes	Milkfat fractions[1]
Bakery products		
Laminated pastries (puff, Danish, and croissant)	Firmness Plasticity Layering properties Flavor	HMF, MMF
Cakes	Structure formation Aeration properties Plasticity Flavor	MMF, LMF
Cookies	Shortening properties Lubricity Antibloom properties Flavor	LMF, MMF
Confectionery Products		
Dark chocolate	Antibloom properties Compatibility with other fats Firmness	HMF
Milk chocolate	Compatibility with other fats Firmness Flavor	HMF
Confectionery fillings	Compatibility with other fats Softness Flavor	LMF, MMF, HMF
Chocolate coatings	Compatibility with other fats Softness or firmness Flavor	LMF, MMF, HMF
Dairy Products		
Spreadable butter	Spreadability Firmness Structure formation Flavor	LMF, HMF
Dairy-based spreads	Spreadability Firmness Structure formation Compatibility with other fats Flavor	LMF, HMF

[1]HMF = high melting fraction, MMF = middle melting fraction, and LMF = low melting fraction.

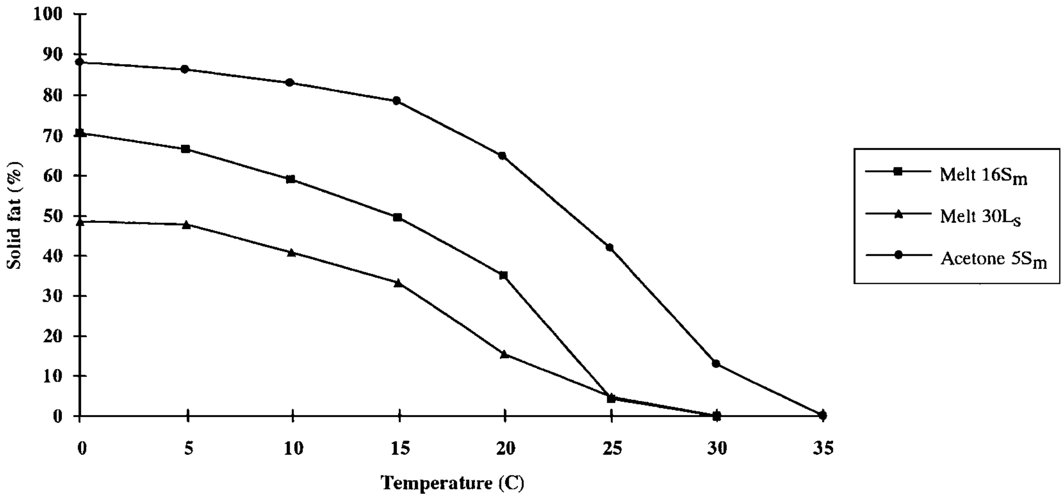

Figure 4. Solid fat content profiles for milk fat fractions of middle melting temperature. Melt $16S_m$ = solid fraction from melt crystallization obtained at 16°C from multiple-step fractionation, Melt $30L_s$ = liquid fraction from melt crystallization obtained at 30°C from single-step fractionation, and Acetone $5S_m$ = solid fraction from acetone crystallization obtained at 5°C from multiple-step fractionation.

remain solid during the initial phases of baking to form a barrier between dough layers and provide a flaky texture. In cookies, the gluten formation between adjacent flour particles is disrupted by coating them with liquid fat, resulting in the short texture characteristic of shortbread cookies. In table spreads, structure refers to the formation of a sufficient solid crystal network to hold the liquid fat and moisture. This network must not be too brittle or too soft for optimal spreadability and stand-up properties.

Table 2 outlines the desired functional attributes and suggested milk fat fractions for use in a variety of food products. A detailed discussion of the precise parameters that are needed to produce a milk fat ingredient for a specific application is outside the scope of this paper. There are too many applications to cover within one paper, and this discussion can be difficult because there are many nuances specific to each customer's individual product. The purpose of this information is to provide a starting point for evaluation of specialty milk fat ingredients. Each end user needs to test these ingredients and work with suppliers to determine the best ingredients for their own applications.

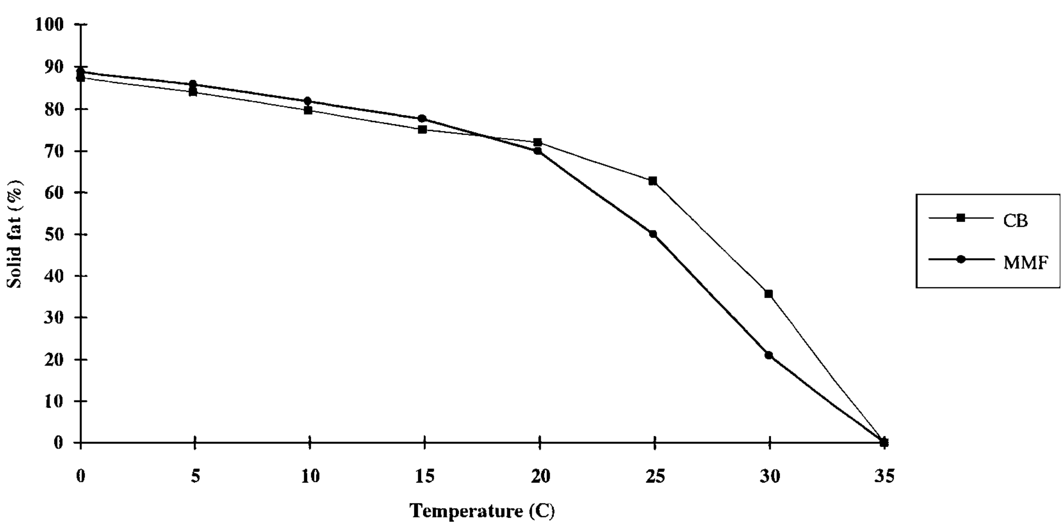

Figure 5. Solid fat content profiles for cocoa butter (CB) and a middle melting fraction (MMF) (7).

There is no substitute for actual testing of the ingredient in the application. Analytical tools are useful but are not always good predictors of performance. For example, Figure 4 shows three fractions that are characterized as middle melting based on melting point. However, the solid fat content profiles are different, and the fractions behave very differently in a product such as a table spread. Just because these are all middle melting fractions, they are not necessarily interchangeable. Figure 5 shows an example of a milk fat fraction that has a solid fat content profile that is very similar to cocoa butter. When this fraction was evaluated in chocolate, it was actually found to promote blood rather than inhibit bloom because of the high percentage of lower melting triglycerides present (7). In this case, information about solid fat content alone was not enough to predict functional performance. Interactions betwen food components is complex, and many of these are not understood or easily predicted. I cannot stress enough the importance of performance testing new ingredients in the actual situation if possible.

SUMMARY

The production of specialty milk fat ingredients in the US is an emerging field. This discussion provides a general overview of the technologies available to modify milk fat properties and the starting points for creating tailored milk fat ingredients. Important aspects of creating and using milk fat ingredients are to understand the needs of the finished application and to learn how to modify milk fat to optimize the desirable qualities. There is a continued need to understand the relationship between subjective analytical tests and functional performance. The true suitability of any ingredient can only be judged by actual performance testing of the ingredient in the product.

The use of fractionation, blending, and texturization technologies gives the dairy industry new opportunities to tailor milk fat ingredients to meet the needs of specific applications and to expand the use of milk fat where it can contribute substantially to flavor and quality.

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