

Technical Report: Milkfat and Related Ingredients Serving Today's Marketplace

Written by:
Ravin Gnanasambandam

PhD, Principal Scientist, Research & Development, Land O'Lakes, Inc.

Moises Torres-Gonzalez

*PhD, Director of Nutrition Research, National Dairy Council**

K.J. Burrington

Dairy Ingredients Applications Coordinator, Wisconsin Center for Dairy Research

Reviewed by: **Rohit Kapoor**

*PhD, Vice President Product Research, National Dairy Council**

Introduction

Milkfat has been harvested for human use for thousands of years. Historically, milkfat and milkfat-based products have found a special place in food habits of all cultures as people all over the world have consumed them. The food landscape today continues to feature milkfat ingredients as an integral component to modern diets. Applications using various forms of milkfat—chilled/shelf-stable desserts, chilled snacks, coffee whiteners, condensed/evaporated milk, cream, fromage frais and quark—had a global market size of \$49 billion in 2015 and is expected to grow to \$53 billion by 2020.¹

Cow's milk contains approximately 3-5% fat (varies by breed) embedded in fat globules that range in size from less than 1 micron to 10 microns.² The milkfat globule is surrounded by a complex membrane consisting of several bioactive compounds, including phospholipids.³ The milkfat is in a liquid or a semicrystalline form, depending on its temperature. While containing primarily triglycerides, milkfat also consists of small amounts of diglycerides, monoglycerides, free fatty acids, phospholipids and cholesterol (sterols) (Table 1).

TABLE 1: MAIN CLASSES OF LIPIDS IN MILK⁴

COMPOUND	% IN MILKFAT
Triacylglycerols	98.3
Phospholipids	0.8
Diacylglycerols	0.3
Sterols	0.3
Free fatty acids	0.1
Monoacylglycerols	0.03
Carotenoids	trace
Fat-soluble vitamins	trace
Flavor compounds	trace

Fat, or triacylglycerol, is made up of fatty acids. While more than 400 individual fatty acids have been identified in milkfat, only 10 to 20 different fatty acids account for 90% of that total. Milkfat contains 70% saturated fats and 30% unsaturated fats.⁵ The possible number of triglycerides that might exist in milkfat is at least 64 million, making it one of the most complex fats in nature.² The fat amount and composition in milk varies due to several factors, including the cow's breed, feed source, stage of lactation and season. The major fatty acids in milkfat are straight-chain fatty acids that are saturated and have 4 to 18 carbons (4:0, 6:0, 8:0, 10:0, 12:0, 14:0, 16:0, 18:0), monounsaturated fatty acids (16:1, 18:1) and polyunsaturated fatty acids (18:2, 18:3).² The melting points of individual triglycerides show a broad range due to the heterogeneity of the fatty acid composition. While short-chain triglycerides such as tributyrin melt at very low temperatures, as low as -75°C (-103°F),⁶ saturated long-chain triglycerides such as tristearin have a melting point of 72°C (161.6°F).⁷ The final melting point of milkfat is 37°C (98.6°F) because higher melting triglycerides dissolve in the liquid fat. This temperature is significant because 37°C (98.6°F) is the body temperature of the cow, and the milk needs to be fluid at this temperature. The heterogeneity of milkfat triglycerides results in a very favorable melting behavior useful in various food product applications.

Milkfat provides long-lasting flavor, mouthfeel, texture and body in a wide variety of food products, including bakery, confectionery, soups, refrigerated and frozen dinners, and desserts. Applications of milkfat and milkfat-based ingredients are found starting on Page 10. Milkfat-based ingredients in food include butter, heavy cream, light cream, half-and-half, evaporated milk, condensed milk and whole milk. Milkfat is favorable to human palates and less processed than refined vegetable fats and oils. Because of this, milkfat contributes to a consumer-friendly label, as evidenced by the current resurgence of butter.

Changing nutritional perspectives on milkfat

Milkfat is one of the most complex dietary fats.⁸ Because 65-70% of the fats in milkfat are saturated fatty acids,⁸⁻¹⁰ full-fat dairy products have been negatively perceived by health professionals. Current U.S. dietary guidelines recommend limiting saturated fat intake to 10% of daily calorie consumption and to choose low-fat or fat-free versions of dairy products.¹⁰⁻¹² The rationale behind these dietary recommendations is that saturated fat raises plasma low-density lipoprotein cholesterol (LDL-C), a biomarker thought to increase the risk of cardiovascular disease (CVD). However, emerging evidence has shown that saturated fat intake may not be directly associated with risk of CVD.¹³⁻¹⁵ This evidence suggests that the relationship between saturated fat, LDL-C and CVD is more complex than once thought. Similarly, neutral or beneficial associations with CVD risk occur with consumption of all fat levels of dairy foods, not only low-fat or fat-free. When considered together, these studies have found that dairy food consumption—regardless of fat content—is not associated with increased risk for CVD.¹⁶⁻²⁴

In addition to higher-fat dairy products being associated with risk of CVD due to their saturated fat content, consumption of higher-fat dairy products has been linked to other health concerns such as obesity and Type 2 diabetes. With regards to obesity, although not conclusive, emerging research indicates that consumption of higher-fat dairy foods may not be associated with obesity risk. Systematic reviews and prospective cohort studies have reported that the observational evidence does not support the hypothesis that high-fat dairy foods contribute to obesity;²⁵ there is no link between the consumption of most dairy foods and long-term weight;²⁶ and higher intake of high-fat dairy products, but not of low-fat dairy products, was associated with less weight gain after 17 years in more than 18,000 women.²⁷ Similarly, other observational studies found that high-fat dairy intake was associated with lower prevalence of global (determined as body mass index (BMI)) and abdominal (determined as waist circumference) obesity in adults;²⁸ and, in adolescents, the highest consumption of full-fat dairy was associated with the lowest changes in BMI after three years.²⁹ Related to Type 2 diabetes, a series of scientific investigations that have looked at blood levels of dairy fat biomarkers (e.g., C15:0, C17:0 and/or C16:1tn-7) as a way to accurately measure dairy fat intake, have found that higher proportions of these biomarkers in blood were associated with a lower risk of Type 2 diabetes³⁰⁻³³ or with improvements associated with glucose metabolism.³⁴ Thus, this growing body of scientific evidence supports reassessing the role of whole and reduced-fat dairy foods in healthy eating

patterns, so that future dietary recommendations can best promote health and reduce chronic disease. Overall, the research on dairy foods' impact on heart health, obesity and Type 2 diabetes is unfolding and represents a significant shift in thinking. However, it is important to conduct more research to understand the link and actual mechanisms of action.

Moreover, the apparent oversimplification of saturated fat as a single compound has contributed to the negative perception of milkfat. Saturated fat is not a single compound, but is rather a very diverse class of fatty acids, each potentially impacting disease risk factors differently. Specifically, saturated fat in milkfat contains short-, medium- and long-chain saturated fatty acids.⁸ Milkfat is one of few foods rich in short-chain and medium-chain fatty acids (SCFAs and MCFAs, respectively), comprising around 13-15%^{8,9} of the total saturated fat content. Metabolism of SCFAs and MCFAs differs considerably when compared with the metabolism of long-chain fatty acids. When digested, MCFAs and SCFAs are readily absorbed, pass directly into the bloodstream and are transported to the liver via the portal vein.²⁵ In the liver, they are immediately used for energy production and, therefore, do not accumulate in the body. Because of their immediate absorption, MCFAs have therapeutic use for people with fat malabsorption problems.³⁵⁻³⁷ Moreover, some reports suggest that medium-chain triglyceride (MCT) might be useful for weight management when included in the diet as a replacement for long-chain triglycerides^{38,39} and for improvement of physical endurance in animal models.⁴⁰ Additionally, an in vitro study has shown that SCFAs and MCFAs have antimicrobial properties toward oral bacteria.⁴¹

Milkfat also contains trans fatty acids (TFA)—vaccenic acid being the most abundant.⁸⁻¹⁰ Although high intakes of industrial trans fatty acids produced via partial hydrogenation of vegetable oils are associated with increased risk of CVD, naturally occurring TFA (such as those present in milkfat) have not been associated with CVD when consumed in typical amounts.⁴²⁻⁴⁴ Another type of trans fat present in milkfat is conjugated linoleic acid (CLA).^{8,9} The main CLA isomer in milk is rumenic acid (cis-9, trans-11 18:2), a fatty acid that has been associated with antiatherogenic and anticarcinogenic effects in in vitro and in vivo studies.^{45,46} In humans, the beneficial effects of CLA on body fat and on plasma lipids have been inconsistent.^{47,48}

Another class of fatty acids found in milk, and possibly the most overlooked type of fatty acids in terms of health promotion, is branched-chain fatty acids (BCFAs).⁸⁻¹⁰ Branched-chain fatty acids are primarily saturated fatty acids with one or more methyl groups. The milkfat content of BCFAs is about 2% of the total fatty acids in cow's milk in the United States.⁴⁹ Researchers speculate that BCFAs play an important role in the development of the human microbiome. BCFAs are major components of the vernix, the white fatty film that covers the fetus in utero.⁵⁰ The fetus swallows the vernix by the third trimester of pregnancy, exposing the fetal gut to BCFAs from an early age. It has been reported that newborn lumen contains BCFAs, leading to speculation that the BCFAs provided by the vernix support colonization of specific organisms of the gut microbiome.^{50,51} Researchers hypothesize that the absence of vernix, as is observed in premature newborns, is related to the incidence of necrotizing enterocolitis (NEC) and a dramatic change in the composition of the premature newborn's microbiota.⁵¹ In fact, BCFA supplementation reduced the incidence of NEC in a neonatal rat model.⁵¹ The studies around BCFAs suggest that these types of fatty acids may be a promising component in perinatal nutrition.

Another important lipid fraction of milkfat is phospholipids. These compounds are found primarily as part of the milkfat globule membrane (MFGM), the membrane that surrounds the lipid globules in milk.⁵² Phospholipids constitute approximately 40% of the total lipids in the MFGM.⁵³ The phospholipids in milkfat include phosphatidylcholine, phosphatidylethanolamine, phosphatidylinositol and phosphatidylserine. Another type of membrane lipid, glycosphingolipids, includes sphingomyelin as the dominant species and gangliosides to a lesser extent.⁵⁴ The potential benefits of phospholipids have attracted attention within the scientific community. In animal studies, phospholipids have been associated with the inhibition of colorectal cancer^{55,56} and reduction of blood cholesterol levels.^{57,58} Additionally, researchers hypothesize that phospholipids may reduce intestinal infections.⁵⁹ Additional research is necessary to confirm this hypothesis.

A pilot human study showed that phospholipids protected the gastric mucosa.⁶⁰ Moreover, sphingomyelin (SM), one of the most abundant phospholipids in the MFGM, plays an important role in the structure of the brain

cell membrane.⁶¹ Results of a recent pilot study conducted in Japan showed that an infant formula fortified with a higher level of SM and a different overall phospholipid profile improved some determinants associated with positive neurodevelopment in preterm infants at 12 and 18 months of age.⁶² Similarly, other studies have reported that MFGM may attenuate the effects of saturated fat on LDL-cholesterol levels,⁶³ may help reduce ear infections in formula-fed infants,⁶⁴ and may improve in vivo resistance to diarrheagenic *E.coli* infection in adults.⁶⁵ The observed effects mentioned above have been attributed to the phospholipid fraction of the MFGM.⁶³⁻⁶⁵ The emerging scientific evidence around milk phospholipids suggests a potential role for these compounds in human health. More research, however, is needed to confirm these preliminary findings and determine the potential for use in food products to support health.

In summary, the fat in whole milk dairy products is distinctively complex in terms of composition and associations with health outcomes. Beyond the saturated fat content, milkfat contains a number of biologically active and potentially beneficial components. Emerging research supports reassessing the role of this unique fat in a healthy dietary pattern in order to promote health and reduce the risk of chronic disease. More research is needed to further understand the health impact of milkfat consumption, either by the different individual fractions or by the whole complex.

Milkfat flavor

Milkfat is an important constituent contributing to the flavor of milk. It contains butyric acid (C:4) and low molecular weight fatty acids (C:4 to C:10) at higher levels than any other fat, adding to the unique flavor of milkfat. Milkfat is also broken down by microbes and lipases, inherently found in milk, producing flavor compounds associated with products like cheese and cultured milk products. More than 120 compounds have been identified in milkfat that contribute to the flavor,⁶⁶ including free fatty acids, methyl ketones, lactones and aldehydes.⁶⁷ Diacetyl and sulfur compounds are also involved in the flavor of milkfat-based products.⁶⁸ Important lactone compounds that contribute to flavor include d-octalactone, d-decalactone and g-dodecalactone.⁶⁹ Short-chain fatty acids, especially C:4 and C:6, also contribute. While fresh milkfat contains no methyl ketones, they are produced when keto acids of milkfat are decarboxylated during aging or processing. These compounds are popularly considered as the main contributor to the rich flavor associated with baked goods that contain butter. Aldehydes, especially hept-4-enal, are claimed to contribute to creamy flavor.⁷⁰

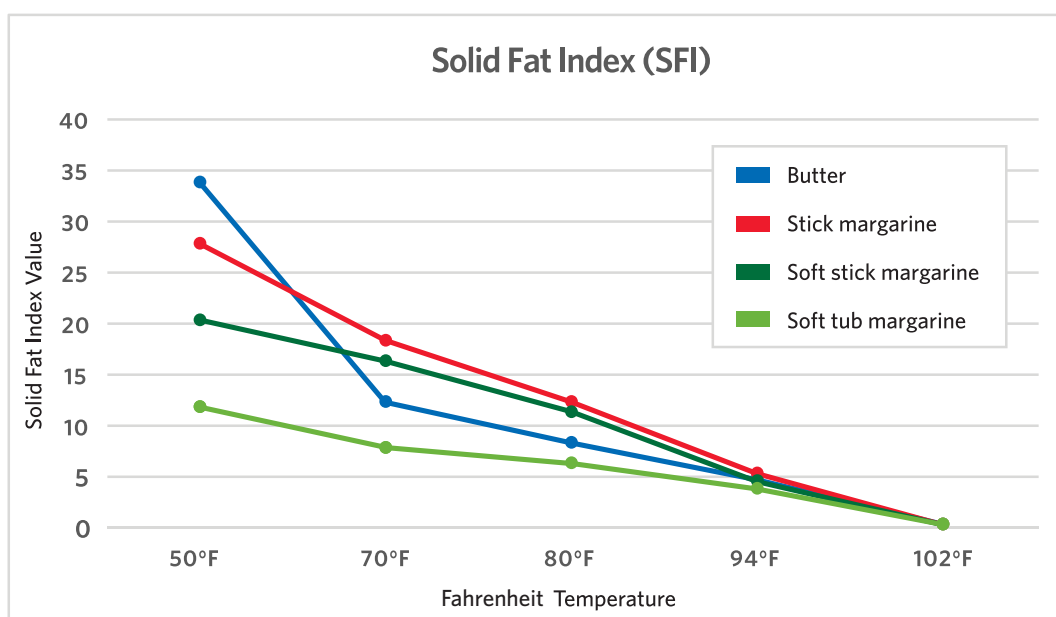
Processing plays an important role in influencing milkfat flavor,⁷¹ and fat is an excellent carrier for flavor compounds. Conversion of flavor precursors to active flavor compounds in milkfat during heating yields flavors that are unique to milkfat.⁶⁷ Flavor compounds soluble in fat release slowly in the mouth, resulting in a long-lasting flavor experience. In butter, the amount and balance of flavor compounds determine the uniqueness of the flavor. All of the butter compounds react together in the matrix in a specific way that yields the unique flavor of butter. The individual compounds may taste distinct at varying amounts in different matrixes. Thus, creating a butter flavor is not as simple as mixing all these individual compounds together. Butter flavor is a dynamic system, changing constantly from the time of production to the end of shelf life. Moreover, butter flavor is also affected by the diet of the animal, the stage of lactation and the season of the year in which it is produced.⁷² Milkfat evaluation, especially butter flavor, may be carried out by a highly trained panel of tasters who evaluate butter aroma and flavor for quality purposes.

Milkfat functionality

Milkfat, due to its heterogeneity of fatty acids and triglyceride content, shows a very complex and unique melt behavior. This distinguishes milkfat from other fats. Milkfat melts well at body temperature, while retaining a solid temperature during refrigeration. Butter has a higher solid fat content at refrigerated temperatures. The ability to remain solid when cold aids in butterfat applications when a solid structure is desirable, such as with puff pastries and sauces. Conversely, the ability to quickly melt at body temperature helps butterfat melt quickly during consumption, which contributes to flavor and salt release for a superior tasting experience without leaving any greasy mouthfeel. Solid fat content or solid fat index of milkfat refers to the percentage of solid fat at a given

temperature. The solid fat content is measured over a range of temperatures to obtain the melting profile of a fat. Solid fat content of butter versus margarines is shown in Figure 1. Pulsed nuclear magnetic resonance, differential scanning calorimetry or dilatometric techniques are used for measuring the solid fat content of milkfat.⁷³ Milkfat provides lubrication and a creamy mouthfeel, while acting as a reservoir for other flavors, especially those arising from lipolysis of fatty acids in products such as in aged cheese. Milkfat can also be fractionated into three major fractions: a high-melt fraction that melts at temperatures above 20°C (68°F), middle-melting fractions that melt between 10-20°C (50-68°F), and a low-melt fraction that melts below 10°C (50°F). Anhydrous milkfat is heated to above 40°C (104°F) to completely melt, and is then cooled slowly to crystallize and separate the high-melt fraction (stearin) and the low-melt soft fraction (olein). This slow crystallization and separation process is repeated with the soft fraction to produce a series of milkfat fractions with a wide range of melting properties and functionality. As butter is difficult to spread at refrigeration temperatures, the low-melt fractions can be useful in producing cold spreadable butter. Hard fractions can be used in confectionery as coating fats and in cheese, chocolates and dough products. It is also possible to tailor the milkfat for targeted application by blending various fractions.⁶⁷ The fractionation process can be an effective way to capitalize on milkfat functionality and opens up countless opportunities for milkfat applications.

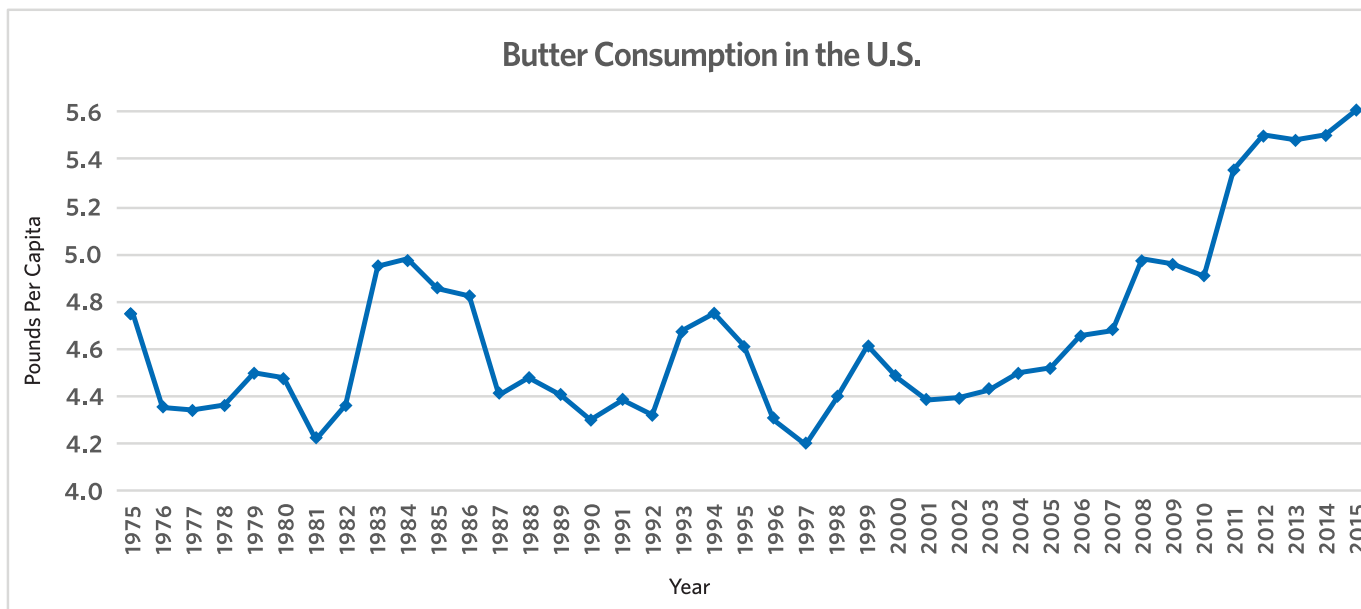
Figure 1⁷⁴



CONSUMER BENEFITS

Milkfat-based products, including butter, have been consumed by people for a very long time. Specifically, butter is viewed by consumers as a tasty and natural product.⁷² However, a higher level of saturated fat and cholesterol content are the main drawbacks for milkfat usage, as dietary recommendations to reduce consumption of saturated fats and cholesterol in order to decrease the risk for heart disease have persisted for many years. In contrast, recent research studies in nutritional sciences (as indicated earlier) are gradually reversing the nutritional perspectives on fat. This new understanding, along with the removal of the Generally Recognized as Safe (GRAS) status of partially hydrogenated fats by the U.S. Food and Drug Administration (FDA), has helped move consumer preference toward dairy fats. Butter is finding its way into consumers' kitchens and enjoying a favorable standing with chefs. This has gradually increased the demand and consumption of butter in the United States, as well as globally.

Figure 2



Source: U.S. Department of Agriculture Economic Research Service

Butter is a versatile ingredient and is frequently chosen by chefs and cooking enthusiasts as their cooking fat for its great taste. Its U.S. per capita consumption has risen to 5.6 pounds in 2015, a 25% increase in the last decade and a 40-year high (Figure 2). World butter consumption in 2018 is projected to be 11,076,000 metric tons.⁷⁵

Products containing milkfat

BUTTER

By U.S. regulations, sweet cream butter and cultured butter contain a minimum of 80% fat, while European butters often contain more than 80% fat. Most of the butter produced and consumed in the United States is sweet cream butter that has a predominantly sweet cream flavor.⁷⁶ Cultured butter (common in Europe) made through fermentation has a “cultured” flavor and is slowly finding favor with U.S. consumers for its distinctive sour flavor attributes.

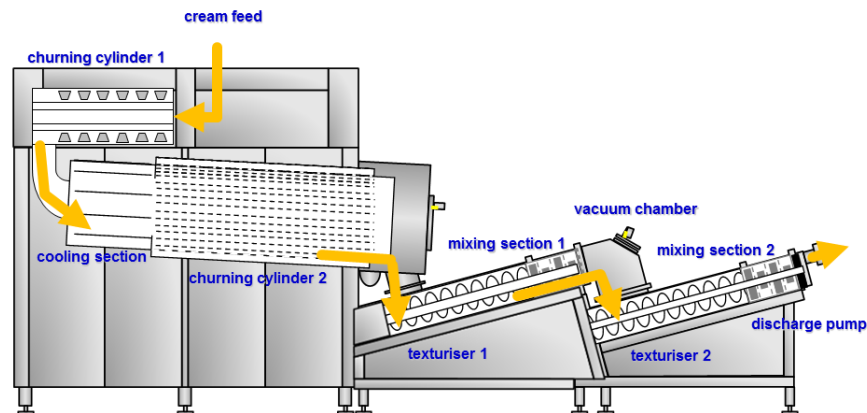
Butter is consumed as table butter as well as an ingredient in various foods. Stipulated by an act of U.S. Congress in 1923, butter shall contain a minimum of 80% fat, made from either milk or cream, with or without salt, and with or without coloring matter. Butter standards represent one of the oldest federal food standards that are still in force today.⁷⁷

Butter is traditionally produced through a churning process in which cream with 40% fat is either churned continuously or in a batch process. Figure 3 illustrates the churning operation that ruptures the cream fat globule and causes the cream emulsion to break down. The rupture of the milk fat globule membrane releases the fat, which then starts to bind and coalesce with other broken fat globules. As a result, the particles of butter grow from tiny specs to rice-sized granules. These granules will continue to grow in size and separate from the liquid phase. At this point, the once homogeneous cream appears broken and the fat granules float in the liquid phase. The liquid phase is drained as buttermilk, while butter granules come together, texturize and are packaged.⁷⁸ Salt is added as either brine or granules to a final salt concentration of about 2%, and the fat content is adjusted to 80%. Unsalted butter is produced by replacing salt with lactic acid and flavors to maintain a pH lower than 4.60, which is required for butter keeping quality. Cream treatment prior to churning includes holding the cream at a specified temperature set point and time. This step, along with optimized churn operations, is critically important

for producing butter of superior quality and yield. Cream treatment, temperature, cream flow rate and churn speed are all important.

Figure 3

Courtesy: Iverson, Inc.



Butter is predominately packaged as ¼-lb sticks. However, butter is also packaged into 1-lb blocks or 50-lb bulk packaging. It has a long refrigerated shelf life and keeps well for more than four to six months.

Other than churning, butter may also be produced using processes in which the milkfat is concentrated via centrifugal separation and cooled via scraped surface heat exchangers to produce 80% or higher fat content.⁷⁸

Codex Standard for Milkfat Products published by the Food and Agriculture Organization (FAO) and standards of identity for dairy food products established by the FDA are two sources followed by the industry and trade for regulatory and legal purposes. Readers are encouraged to refer to these sources for more information on milkfat products' standards and identity.^{79,80}

ANHYDROUS MILKFAT (AMF)

Anhydrous milkfat (AMF) and butter oil are products that consist of almost all milkfat. Defined by the Codex Alimentarius Commission's standard CODEX STAN 280-1973, anhydrous milkfat, milkfat, anhydrous butter oil and butter oil are products derived from milk and/or products by means of processes that result in almost total removal of water and nonfat solids.

According to Codex and the Code of Federal Regulations, (CFR) at 7 C.F.R §58.347, AMF contains at least 99.8% milkfat, but can be made from milk and/or products obtained from milk, such as cream or butter of different ages. Use of alkali to neutralize free fatty acids is permitted in the production of butter oil, but not AMF. If the neutralization option is used, the resulting product then falls outside the definition of AMF and into one of the butter oil categories.⁸¹ Butter oil must contain at least 99.6% milkfat. Raw material and processing specifications are the same as for anhydrous butter oil.

AMF is the preferred material for milkfat fractionation that furthers the use of milkfat into various applications. Typically, AMF is produced from pasteurized cream (40% fat) that is concentrated to high-fat cream (70-80% fat), followed by phase inversion (going from an oil-in-water emulsion to a water-in-oil emulsion) and further concentration to 99.6% fat.⁸¹ It is then vacuum-dried to remove residual moisture.

Cultures all over the world have used AMF and butter oil for centuries in traditional cooking and food preparation. In the Indian subcontinent and the Middle East, ghee, which has a similar composition to butter oil, is produced by boiling off the water and removing the nonfat solids, allowing it to produce a unique, pronounced caramelized flavor. Ghee is a chosen condiment for many traditional foods in India and the Middle East, and is also used as a frying medium and an ingredient in sweetmeats and savory foods.

CREAM

Cream is another important milkfat-based product. Cream is produced by centrifuging pasteurized milk to achieve varying levels of milkfat depending on the desired characteristics of the final product. Varying in fat content and applications, cream is an oil-in-water emulsion, thus, it is a perishable product with a refrigerated shelf life of a few days. Homogenizing helps improve the physical stability of cream emulsion by reducing the fat globule size. This, along with the addition of other optional ingredients such as emulsifiers and stabilizers, helps prolong the shelf life of cream. Commercial cream production methods have evolved over the years to deliver high-quality cream products enjoyed by consumers.⁸²

Standards of identity established by the FDA⁸³ regulate cream products, specifying the percent fat ranges and the optional ingredients that can be added to the cream. Half-and-half, which is used primarily as a coffee-whitening agent, is produced from milk and cream at a milkfat content not less than 10.5% and not more than 18%. Light cream has a minimum milkfat content of 18% and a maximum of 30%, and is useful in culinary applications, such as sauces and soups, and as a topping for dessert. Light whipping cream used in whipped cream for dessert toppings must contain a minimum of 30% milkfat and not more than 36%. For applications that need a solid texture and stiff whipping, heavy cream may be used and must contain a minimum of 36% milkfat. Optional ingredients that may be used in these cream products include emulsifiers such as mono- and diglycerides of fatty acids; stabilizers such as carrageenan; nutritive sweeteners; and flavoring ingredients such as fruits and fruit juices and natural and artificial flavorings.⁸⁴ Heavy cream at about 40% fat is also used in the production of butter and is a preferred raw material for AMF production.

SOUR CREAM

Soured or cultured cream is another milkfat-based ingredient that is increasingly popular in food products and culinary applications as American consumers are exposed to new global foods and flavors. According to the standard of identity established by the FDA, sour cream is produced by fermenting the pasteurized cream using lactic acid-producing bacteria. Sour cream contains not less than 18% milkfat, except when the food is characterized by the addition of nutritive sweeteners or bulky flavoring ingredients. The weight of the milkfat is not less than 18% of the remainder, obtained by subtracting the weight of such optional ingredients from the weight of the food, but in no case does the food contain less than 14.4% milkfat. Sour cream has a titratable acidity of not less than 0.5%, calculated as lactic acid. Sodium citrate in an amount not more than 0.1% may be added prior to culturing as a flavor precursor. Certain optional ingredients such as rennet, salt, nutritive sweeteners, colors and flavors can be included as needed to prevent syneresis and improve shelf life. In place of lactic acid-producing bacteria, acidifying agents can be used, creating a product called acidified sour cream.⁸⁵

CONCENTRATED MILK

Concentrated or condensed milk is produced by partial removal of water from milk. The milkfat and total milk solids contents of condensed milk are not less than 7.5% and 25.5%, respectively. It is pasteurized, but homogenization is optional. Vitamin D, approved colors and flavors, and fruit juices are other optional ingredients that can be added to condensed milk.⁸⁶

Condensed milk is also found in the form of sweetened condensed milk (SCM), with sugar added. The terms "condensed milk" and "sweetened condensed milk" are often used synonymously today by the consumer. However, the FDA has established separate standards of identity for these products, and naming should be distinct for food-labeling purposes. Sweetened condensed milk is a very thick, sweet product that, when canned, lasts for years without refrigeration if unopened. Condensed milk is used in numerous dessert dishes, including bakery, beverages, desserts and toppings. Sweetened condensed milk can contain not less than 8% by weight of milkfat and not less than 28% by weight of total milk solids. The quantity of nutritive carbohydrate sweetener used is sufficient to prevent spoilage. The food is pasteurized and may be homogenized.⁸⁷

Evaporated milk is the liquid food obtained by partial removal of water only from milk. It contains not less than 6.5% by weight of milkfat, not less than 16.5% by weight of milk solids that are not fat, and not less than 23% by weight of total milk solids. Evaporated milk contains added vitamin D. It is homogenized, sealed in a container and processed by heat either before or after sealing to prevent spoilage. Vitamin A, carriers for vitamins A and D, emulsifiers, stabilizers, approved colors and flavors may be added.⁸⁸

EGGNOG

Eggnog is a food containing optional dairy ingredients such as cream, milk, partially skimmed milk or skim milk—used alone or in combination—in addition to egg yolk-containing ingredients and nutritive sweeteners. Eggnog contains not less than 6% milkfat and not less than 8.25% milk solids that are not fat. The food shall be pasteurized or ultrapasteurized and may be homogenized. Flavoring ingredients and color additives may be added after the food is pasteurized or ultrapasteurized.⁸⁹

DAIRY POWDERS

Another category of milkfat ingredients is dairy powders, which are produced by drying liquid dairy products to concentrate the solids and fat. Dry whole milk is the product obtained by removal of water only from pasteurized milk that may have been homogenized. According to the CFR, it contains not less than 26% but less than 40% by weight of milkfat on an as-is basis. Alternatively, dry whole milk may be obtained by blending fluid, condensed or dried nonfat milk with liquid or dried cream or with fluid, condensed or dried milk, as appropriate, provided the resulting dry whole milk is equivalent in composition to that obtained from milk.⁹⁰ Similar to dry whole milk is whole milk powder (WMP), which regulated by Codex standards. WMP allows protein adjustment to a minimum of 34% milk solids not fat.



Dry cream is the product obtained by removal of water from pasteurized milk or cream, or from a mixture of milk and cream to a minimum of 40% but less than 75% milkfat.⁹¹ Optional ingredients allowed in dry products include emulsifiers, stabilizers, anti-caking agents, antioxidants, nutritive carbohydrate sweeteners, and approved colors and flavors.

MILKFAT INGREDIENTS RICH IN PHOSPHOLIPIDS

Milkfat globule membrane (MFGM), one of the most complex biological membranes, consists of phospholipids, glycolipids, glycoproteins, glycerides, fatty acids and enzymes.⁹² Milk phospholipids, together with proteins, play an important functional role of maintaining milk fat globule integrity. As discussed earlier, emerging research has linked milk phospholipids to several health endpoints, including regulation of cholesterol and reduced risk of CVD. Additional research studies in human populations are needed to confirm these preliminary findings. Milk phospholipids have also been studied for their emulsifying and emulsion stabilizing properties and as whipping agents in food applications.

Buttermilk, a by-product of cream churning, and butter serum, a by-product of anhydrous milkfat production, are two major sources of milk phospholipids.³ Because milk phospholipids are predominantly found in MFGM, the method of disruption of MFGM and further separation and purification methods influence the milk phospholipid types and composition. Studies have shown variations in the yield and concentration of milk phospholipids depending on the method of isolation. Butter serum is by far the richest source of milk phospholipids, and studies show preparation of ingredients from butter serum that contain more than 30% phospholipids.⁹³

Whey protein phospholipid concentrate (WPPC), previously known as whey cream, is another phospholipid-rich ingredient available for food applications. WPPC is a by-product of whey protein isolate (WPI) manufacture and is produced during the microfiltration step of WPI manufacture.⁹⁴ Milk and its components have a positive consumer connotation as being natural and wholesome, which is an added incentive for exploiting milk phospholipids as a commercial food ingredient for its functional and nutraceutical attributes.

The resurgence of milkfat-based products has revitalized consumer interest in new and novel milkfat-containing products and ingredients. Dairy processors constantly strive to create new, versatile and label-friendly milkfat based-products using approved processing methods while maintaining the natural benefits of dairy.

Applications of milkfat and milkfat-based ingredients

As discussed earlier, milkfat ingredients contribute unique functionality and flavor that enable their use in a wide variety of food applications.⁹⁵ Though milkfat could be used in almost any food application in which a fat source is needed, primary applications using milkfat ingredients are dairy and bakery products, confections, dry mixes, snacks, soups, sauces, and frozen and ready-to-eat-meals.⁹⁶ The choice of milkfat ingredient depends on its composition, functionality and cost. Cream and butter contain some of the highest levels of moisture, which can limit their use because of shelf-life concerns or the moisture requirements of the desired application. Ingredients such as AMF, butter oil, butter powders, dry cream and WPPC have additional applications due to their lower moisture content.

DAIRY PRODUCTS

Cream is the milkfat ingredient of choice for dairy products such as cheese, fluid milk, ice cream, yogurt, sour cream and other fresh dairy products. In countries where there is an abundance of fluid milk and cream, consumers benefit from the flavors and mouthfeel contributed by fresh cream in all of these products. In ice cream and other dairy products, milkfat contributes to the flavor of the product through its own rich, creamy flavor. These flavors are developed by hydrolysis, oxidation and processing, and by modifying the flavor perception of the product.⁹⁷ The best source of milkfat for ice cream is fresh cream. However, frozen cream, plastic cream (cream that has been separated twice), unsalted butter and anhydrous milkfat (butter oil) can be good alternate sources if stored and handled to preserve flavor quality. During the freezing process, ice crystals form, and air is incorporated into the mix, destabilizing the milkfat globules, which leads to partial coalescence and formation of clumps of fat globules. These fat clumps help to promote air incorporation and stabilization of the small air bubbles incorporated during whipping of the mix.⁹⁸

Butter, butter oil or AMF can be used in processed cheese to increase the fat content or to adjust for a reduction of fat in dry matter of the material after the addition of emulsifying salts or other fat-free ingredients. Adding milkfat reduces the viscosity of the processed cheese and gives it a softer texture.⁹⁵ Though low-fat versions of fluid milks, ice cream, cheese and yogurt have been prevalent in recent history, higher-fat products are now being introduced as nutritional news about milkfat improves. In countries where there is not enough fresh fluid milk or cream to make these dairy products, it becomes necessary to make recombined dairy products. In this situation, it is common for countries to use milk powders, such as skim milk powder with added AMF (or butter oil) or whole milk powder, to make recombined milk. Fluid cream, cultured milk products, ice cream, cheese and even butter can be made by recombination with AMF and milk powders.⁹⁹

WPPC is a dairy ingredient that contains both whey protein and fat. Unlike other milkfat ingredients, it provides functionality from both protein and fat.¹⁰⁰ Characterization of the functional properties of four commercial WPPC ingredients has been recently published.¹⁰¹ Minimal application work has been published on the use of WPPC in refrigerated dairy products or other foods, but there has been some work published on its use in ice cream. In a study by Bund,¹⁰² WPPC blends with delactose permeate (a by-product of lactose manufacture) were used to replace a portion of nonfat dry milk in ice cream. WPPC has also been used as a replacement for the emulsifiers mono- and diglycerides and polysorbate 80 in a study by Levin.¹⁰³ When replacing nonfat dry milk in ice cream, WPPC blends

worked better to match flavor and melt characteristics when used as partial emulsifier replacement than as a total replacement.

BAKERY PRODUCTS

Fat ingredients such as butter and AMF have multiple functions in bakery products. They impart shortening, richness, tenderness and flavor while also providing aeration for improved leavening and volume. They promote desirable structure and texture qualities such as flakiness in puffed pastries, pie crust and Danish pastry. Milkfat provides lubrication to prevent the wheat gluten from adhering together, delaying staling. Milkfat also provides moisture retention for shelf-life improvement.¹⁰⁴ Though butter is by far the fat source of choice for baking because of flavor, it tends to have more variability in its functionality due to the method of manufacture.¹⁰⁵ For this reason, milkfat fractionation to produce customized milkfat ingredients has shown better and more consistent functionality for baking.⁹⁶



WPPC has been evaluated in layer cakes as a replacement for whole eggs.¹⁰³ This study replaced the whole egg based on its protein content with an equivalent amount of WPPC and added water. A 100% replacement of whole egg with WPPC produced cakes with similar texture but decreased contour.

CONFECTIONS

Butter, cream and AMF are all used in confectionery products. Butter and cream are often used in high-quality caramels, toffee and cream fillings for their premium flavor. AMF or butter oil is often used in chocolate at a level of 2-3% to control hardness. They also could be used in compound coatings for imitation chocolates. The addition of milkfat can also help inhibit fat bloom (off-white, unappetizing coating on the surface of the chocolate).¹⁰⁶ Milkfat can make up as much as 30% of the fat phase in chocolate, but the higher the level used, the softer the chocolate, due to the low-melting glycerides in milkfat that lower the melting point of the chocolate.⁹⁵



In caramels, use of WPPC as a partial replacement of the protein in sweetened condensed skim milk and as a total replacement for soy lecithin increased the cold flow and decreased the hardness of the caramels.¹⁰³

DRY MIXES

Products such as soups, sauces, pudding mixes, coffee whiteners, beverage mixes, pancake mixes and other bakery mixes can obtain the flavor and mouthfeel of butter by using butter powder due to its good dispersability.⁹⁹ For countries with a tropical climate, butter powder is much easier to handle and store than butter, so it could be used in dry-mix, ready-to-eat products such as soups, sauces and meals.

SNACKS

Butter is a popular milkfat ingredient for snacks because of its flavor characteristics and ability to work well with both sweet and savory flavors. Premium microwave popcorn is one snack that often has butter listed as an ingredient and in the name of the product. Heating butter produces lactones from the fatty acids, which provides the characteristic flavor and aroma of cooked butter. The golden color of butter also provides visual appeal to snacks, especially when topically applied or used for popcorn. Butter and AMF also act as flavor carriers for spices, herbs and other fat-soluble ingredients that may be used as seasonings for snacks. Like baked products, pretzels and crackers will also benefit from the functionality of butter (see Table 2 below).



Table 2

INGREDIENT	FUNCTIONALITY	APPLICATIONS
Butter	Flavor/mouthfeel	All foods
	Structure formation	Baked products
	Emulsification	Sauces, soups, dressings, confections
	Aeration	Baked products, frosting
	Plasticity	Chocolate, baked goods
	Texture	Chocolate sauces, baked products, coating
Butter powder	Similar to butter's functionality with extended shelf life and greater ease of handling and storage, free-flow properties	Ideal for dry mix products (i.e., beverage, sauce and gravy mixes; can be used in other applications that use butter)
Anhydrous milkfat	Flavor/mouthfeel	Chocolate, caramel, toffee, praline
	Anti-bloom	Chocolate, confections
	Flavor carrier	Crackers, chips, hard candy
	Prevents stickiness	High sugar solutions
	Texture	Reconstituted whole milk, croissants, chocolate confections, baked products, mashed potatoes, ice cream
Cream and concentrated milk	Flavor/mouthfeel	Soups, sauces, confections, beverages, baked products, chocolate
	Texture	Soups, sauces, confections, beverages, chocolate
Concentrated or plastic cream	Flavor/mouthfeel	Soups, sauces, confections, ice cream, chocolate, beverages, dips, dressings
Whey protein phospholipid concentrate (WPPC)	Water binding, heat stability, emulsification; replaces functionality of whole egg and partial replacement of chemical emulsifiers	Baked products, confections, ice cream, processed cheese, nutrition bars and beverages; provides dairy source of phospholipids for nutritional applications
Buttermilk and buttermilk powder	Browning, emulsification, water binding, heat stability, good solubility, aeration, flavor enhancement	Baked products, confections, dairy products, soups and sauces; provides dairy source of phospholipids for nutritional applications

SOUPS, SAUCES AND PREPARED FOODS

Milkfat is most often used in the form of butter, AMF or even as cream in soups and sauces. Butter and cream have a clean-label appeal and provide flavor and functionality. Butter provides smoother, thicker texture, glossier appearance and well-rounded flavor in a soup or sauce.¹⁰⁷

Conclusion

Current consumer trends related to clean label are driving food companies to proactively move away from ingredients such as hydrogenated oils to “cleaner” ingredients such as butter and cream for their food products. Moreover, emerging research is changing nutritional perspectives related to milkfat. This represents a significant opportunity for milkfat, milkfat-based ingredients and high-fat dairy products to be the choice for food manufacturers to effectively meet consumer needs. U.S. dairy suppliers offer a variety of traditional butter and milkfat applications and continue to innovate to meet the evolving needs of global customers. Whether for foodservice applications or food manufacturing processes, discover why milkfat ingredients from the United States are an attractive, quality-driven option in the dairy fat supply chain at ThinkUSAdairy.org.



Biographies



RAVIN GNANASAMBANDAM

Dr. Ravin Gnanasambandam is a Principal Scientist at Land O Lakes, Inc. in Arden Hills, Minnesota, where he has been working for 15 years. His expertise includes Dairy Foods, Fats and Oil Chemistry and Functionality, Role of fats in food product quality and acceptability, product and process development, and commercialization. Dr. Gnanasambandam was instrumental in the development and commercialization of several successful dairy foods and beverage products over the past 20 years, and has over 25 years of experience in Food Science and Technology. Dr. Gnanasambandam has a Ph.D in Food Science from Kansas State University and degrees in Veterinary and Animal Sciences from AP Agricultural University, India.



MOISES TORRES-GONZALEZ

Dr. Moises Torres-Gonzalez is Director of Nutrition Research at the National Dairy Council (NDC), where he serves as the subject-matter expert in dairy fat and dairy proteins. Dr. Torres-Gonzalez earned a bachelor's in Biochemical Engineering with a major in biotechnology and food technology at Instituto Tecnológico de Colima and a master's in Biochemical Engineering at the Instituto Tecnológico de Veracruz, plus a master's and doctorate in Nutritional Sciences from the University of Connecticut. He has a strong background in cholesterol and fatty acid metabolism and their implications on human cardiometabolic health, plus has authored or co-authored more than 15 peer-reviewed scientific articles and written extensively on dairy and human health.



K.J. BURRINGTON

Kimberlee “K.J.” Burrington is Dairy Ingredients Applications Coordinator for the Wisconsin Center for Dairy Research in Madison, Wisconsin (USA). Her current research projects focus on dairy ingredient functionality and applications, with an emphasis on yogurt, nutrition bars and protein-enhanced beverages. She has over 25 years of experience in product development, having worked at Ridgeview Industries, the Keebler Company and as a baking industry consultant. She is a Certified Food Scientist and member of the Center of Excellence Committee of the American Dairy Products Institute. Burrington has a bachelor's and a master's in Food Science from the University of Wisconsin-Madison.

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