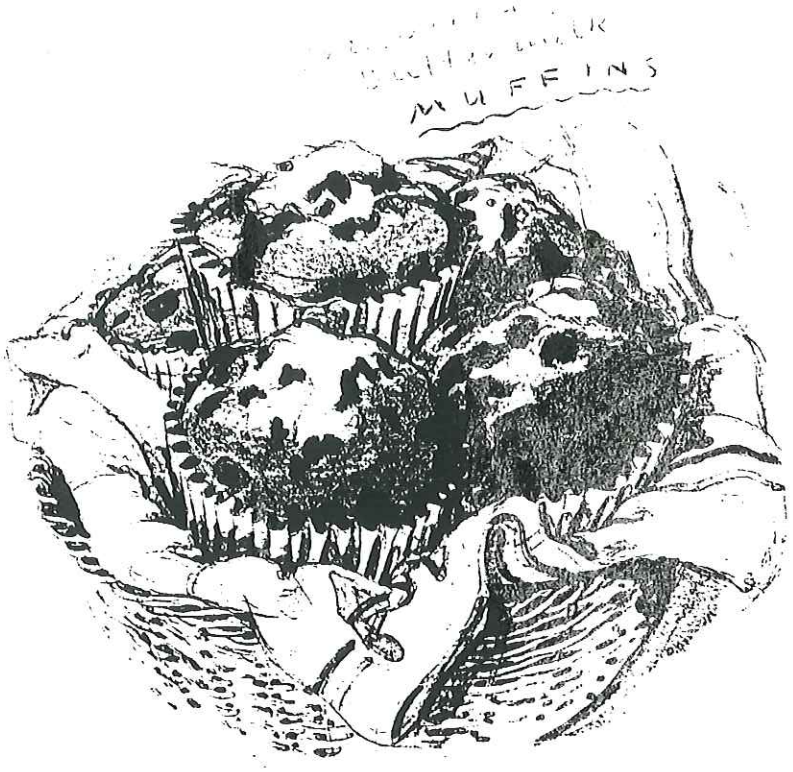


Lactose

Dairy Ingredient Application Guide

DAIRY MANAGEMENT INC.

American Dairy Products Institute

DAIRY MANAGEMENT INC.

America's
Dairy
Farmers

Dairy Management Inc. (DMI) is a nonprofit management, planning and marketing organization formed in 1995 by the National Dairy Board (NDB) and the United Dairy Industry Association. DMI manages the people and resources of NDB, the National Dairy Council and American Dairy Association. DMI maximizes dairy producer promotion checkoff funds by conducting integrated programs in marketing, communications, promotion, education and research for U.S.-produced dairy products on behalf of America's dairy farmers.

DMI Mission

To increase demand for dairy products through the development and execution of an industry-wide, market-driven business plan that invests resources in a strategic manner and provides the best possible economic advantage to dairy farmers.

DMI Strategic Intents

- Increase domestic consumption and expand world markets for U.S. dairy products.
- Unify industry efforts through a coordinated planning system.
- Develop coordinated efforts with farmer cooperatives and processors to leverage efforts to increase industry sales.
- Assure all industry efforts are market-driven.
- Evaluate operational efforts and refine processes to ensure maximum use of funds.

The purpose of this Dairy Ingredient Application Guide is:

- To provide product developers with a working knowledge of the various functional and sensory attributes of dairy ingredients.
- To serve as a reference for product developers formulating foods using dairy ingredients.
- To assist product developers in formulating high-quality, wholesome foods using dairy ingredients.

RECYCLED PAPERS RECYCLABLE

The American Dairy Products Institute (ADPI) is the nonprofit national trade association of the processed dairy products industry. It is a result of mergers of the American Dry Milk Institute, the Whey Products Institute and the Evaporated Milk Association. Processed dairy products within the scope of ADPI activity are: condensed and dry milks; evaporated milks; condensed, dry and modified whey products; lactose; and cheese.

ADPI Mission

To promote the acceptance and utilization of dairy products both nationally and internationally, to maintain liaison and represent the industry in dealings with government agencies and regulatory bodies, to support technical and marketing research, and to assemble and disseminate statistics and other information about dairy products.

ADPI Goals

- Promote the growth and development of dairy products represented by the Institute.
- Provide a strong, effective voice for its members.
- Provide assistance to members through the dissemination of general, technical, statistical and promotional information.
- Represent members' interests in furthering quality improvements and harmonization of standards relating to dairy products both nationally and internationally.
- Enhance relationships and coordinate efforts with industry organizations and applicable governmental bodies.
- Provide opportunities for affiliate, utilization and individual members to interact with member processors.

What is Lactose?

Lactose is the primary carbohydrate found in mammal's milk and is often referred to as milk sugar. It is the first and only carbohydrate every newborn mammal consumes in significant amounts.

Lactose is a natural disaccharide consisting of one galactose and one glucose unit. It is chemically, physically and microbiologically stable, and is highly compatible with other ingredients.

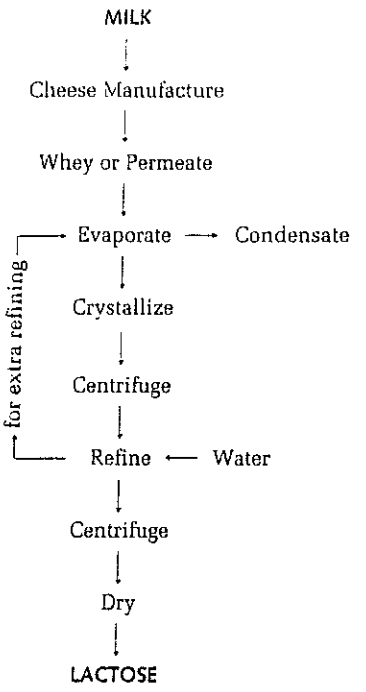
Lactose is isolated from dairy products such as whey and whey permeate, which is available after the production of cheese and/or caseinates. (See Figure I-i.) The basic principle of lactose production is the removal of water from whey by evaporation to increase the concentration of lactose. The condensed whey, with approximately 60% total solids at 140°F (60°C), is then gradually cooled to allow crystallization and separation of lactose. From this point, various types of lactose can be produced.

Chemically, lactose exists in two isomeric forms, α and β. Lactose is commercially available as spray-dried lactose and crystalline lactose. Lactose derivatives include lactose hydrolysates, lactitol, lactulose and lactobionic acid. The composition and description of lactose is defined in 21 CFR 168.122 and the Food Chemicals Codex (see pages A-3 and B-1).

Lactose and its derivatives are capable of sweetening foods, influencing crystallization, adding viscosity, contributing to nutrition and enhancing flavors. Lactose itself has no aftertaste and has a clean mouthfeel.

Figure I-i

Key Steps in Lactose Manufacturing



Why Use Lactose and Lactose Derivatives?

Lactose's oldest application is in the pharmaceutical industry, where it acts as a carrier and filler-dilutant in solid dosage forms like tablets and capsules. In recent years, lactose has been gaining recognition as a food ingredient, but because of its low sweetness level and low solubility, many product developers are not aware of its capabilities. Interestingly, the benefits in using lactose as a food ingredient are a direct result of these characteristics.

Today we see many diverse food applications for lactose because of its relative sweetness, browning ability, protein stabilizing qualities, alteration of crystallization, flavor enhancement, selective fermentation and nutritive qualities.

An expanding area where lactose is useful is in instantizing, or increasing the dispersibility of certain foods. Products are prepared containing 15% to 50% lactose, spray-dried and then instantized by moistening and redrying. This allows some of the lactose to crystallize; the particles then agglomerate, becoming free-flowing and capable of dispersing rapidly.

Specific functions and food applications include using lactose to increase viscosity or improve texture without making a food too sweet. For example, lactose is sometimes used in the manufacture of beer. Depending on the yeast used in the beer formulation, lactose may or may not be fermented. When it isn't fermented, it remains in the finished product, increasing viscosity and improving mouthfeel and flavor.

In the meat and sausage industry, lactose can be added to the raw meat formulation as a carbohydrate source for fermentation. Because it's a reducing sugar, lactose readily reacts with proteins by the Maillard reaction, contributing to controlled browning of these products.

Lactose is added to salad dressings, soups and sauces to enhance flavor and assist in stabilization. Because of its free-flowing properties, lactose can be used in dry mixes such as soups and sauces. It is this free-flow property along with its excellent adsorption properties that makes lactose an excellent carrier for flavors and high-intensity sweeteners.

The confectionery industry uses lactose in certain types of candy because it changes the crystallization behavior of other sugars, improving body, texture, chewiness and shelf life.

In the baking industry, lactose can enhance the creaming properties of shortenings to improve product quality and give increased loaf volume. In addition, lactose readily reacts with proteins by the Maillard reaction giving baked goods a highly flavored, desirable golden-brown color. Carmelization by heat during baking also contributes flavor and color. And lactose is not fermented by bakers' yeast, so its functional properties are effective throughout baking and during storage.

One of the most important lactose applications is infant formula. Lactose is used to correct the balance between carbohydrate and protein in breast milk replacers based on cows milk. Due to its relatively slow digestion, energy is provided by the lactose to the infant over a period of several hours. Because of its bifidogenic activity, lactose is considered critical to the establishment of a healthy intestinal flora.

Finally lactose impacts mineral absorption, enhancing absorption of calcium as well as other essential trace elements.

Table I-i

Typical Uses of Lactose

- Agglomerated or instantized preparations
- Buttermilk
- Cakes and pastries
- Canned and frozen fruit
- Canned and frozen vegetables
- Caramels, fudge and tableted candies
- Cheese foods and spreads
- Chocolate
- Cookies and cookie sandwich fillings
- Cordials and liquors
- Corn curls
- Cottage cheese and cottage cheese dressing
- Dietetic and diabetic foods
- Drink mixes
- Flavor carrier
- French fries
- Geriatric foods
- Health foods
- Icings
- Infant food formulas
- Instant coffee
- Instant potatoes
- Jellies and preserves
- Meat products
- Modified skim milk
- Monosodium glutamate extender
- Party dips
- Pie crusts and pie fillings
- Powdered coffee creamer
- Puddings
- Salad dressings
- Sherbet, frozen desserts and high-solids ice cream
- Simulated mother's milk
- Sour cream
- Spice blends
- Starter cultures
- Sweetened condensed milk

Source: Foremost Foods Co. (1981).

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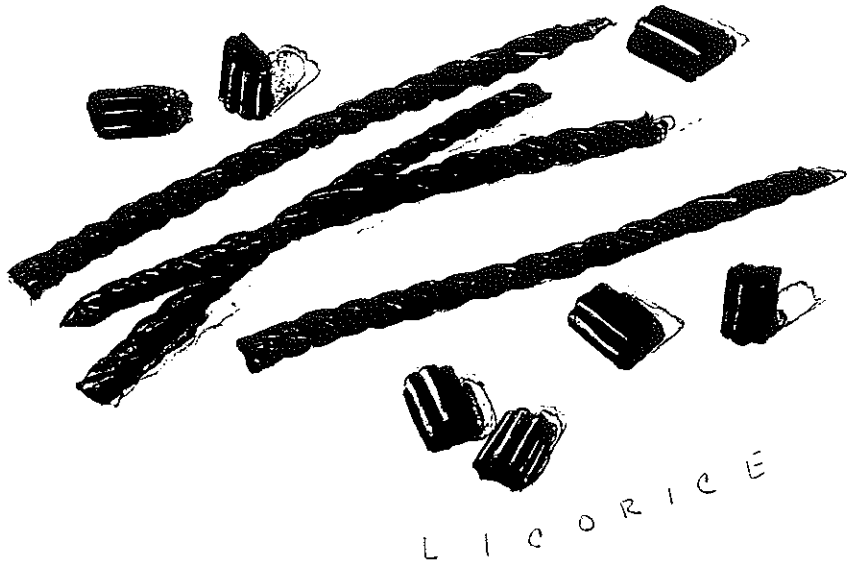
Composition/Properties



Definition of Lactose

Lactose is the primary carbohydrate found in mammal's milk and is often referred to as milk sugar. It is the first and only carbohydrate every newborn mammal consumes in significant amounts.

Lactose is a natural disaccharide consisting of one galactose and one glucose unit. It is chemically, physically and microbiologically stable, and is highly compatible with other ingredients.

The biosynthesis of lactose follows a complex pathway starting from glucose, which is first transformed into galactose. The final step is coupling the galactose to glucose by galactosyltransferase and α-lactalbumin. The latter is unique to the mammary gland and is under hormonal control. Lactose forms the major part of milk's dry matter content. (See Table A-I.)

The lactose content of milk varies by species. For example, human milk contains about 7% lactose, whereas cows milk is only about 4.6% lactose. The high concentration of lactose in human milk suggests one of lactose's primary applications—lactose enrichment of cows milk-based breast milk substitutes, i.e. infant formula.

Lactose is isolated from dairy products such as whey and whey permeate, which is available after the production of cheese and/or caseinates. (See Figure I-i, p. iii.) The basic principle of lactose production is the removal of water from whey by evaporation to increase the concentration of lactose. The condensed whey, with approximately 60% total solids at 140°F (60°C), is then gradually cooled to allow crystallization and separation of lactose.

From this point, various types of lactose can be produced. Separation of the crystal mass and subsequent drying results in a yellow or yellowish colored product called edible lactose. It still contains a small amount of whey proteins and minerals. The yellow color is caused by riboflavin, better known as vitamin B2. Refining of this product results in what is known as refined edible lactose. The purest form of lactose, which is used in the pharmaceutical industry, is obtained by repeated refining.

Chemically, lactose exists in two isomeric forms, α and β. Lactose solutions strive for a state of equilibrium between the α and β forms by mutarotation, which is accompanied by a change of optical rotation.

At room temperature, the equilibrium between the α and β forms results in a solution of 38% α and 62% β lactose. Each form can exist in a crystalline state. The most common is α lactose monohydrate, which can be produced by crystallization at appropriate temperatures. As the name indicates, it contains one molecule of water of crystallization.

Table A-I

Average Composition of Whole Cows Milk

Water	87.2%	Dry matter:	Fat	3.7%
Dry matter	12.8%		Protein	3.5%
	100.0%		Lactose	4.9%
			Minerals	0.7%
				12.8%

Source: USDA Agricultural Handbook No. 8

Definition of Lactose (continued)

β lactose is formed by crystallization at temperatures exceeding 200°F (93.5°C) and does not contain water of crystallization. It is therefore known as anhydrous lactose.

Lactose is commercially available as spray-dried lactose and crystalline lactose. Lactose derivatives include lactose hydrolysates, lactitol, lactulose and lactobionic acid.

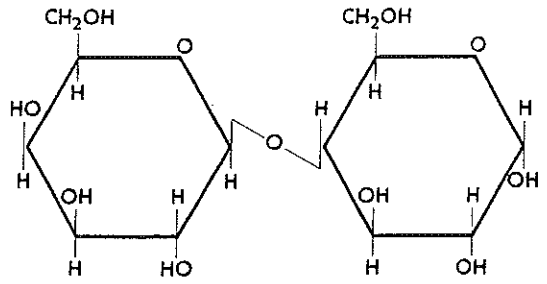
Lactose and its derivatives are capable of sweetening foods, influencing crystallization, adding viscosity, contributing to nutrition and enhancing flavors. Lactose itself has no aftertaste and has a clean mouthfeel.

Figure A-1

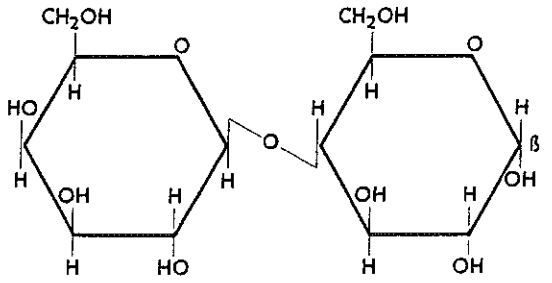
Molecular Structure of Lactose

α lactose monohydrate $C_{12}H_{22}O_{11}{}^{*}H_2O$

β lactose, or anhydrous lactose $C_{12}H_{22}O_{11}$



α Lactose



β Lactose

Composition of Lactose

According to 21 CFR 168.122 lactose is the carbohydrate normally obtained from whey. It may be anhydrous or contain one molecule of water of crystallization or be a mixture of both forms.

The lactose content is not less than 98%, with the sulfated ash content not more than 0.3%, both on a dry basis. The pH of a 10% solution is not less than 4.5 nor more than 7.5.

Table A-II

Typical Composition of Lactose Products (%)

Component	Grade			
	Fermentation	Crude	Edible	National Formulary
Lactose	98.0	98.4	99.0	99.8
Non-hydrate moisture	0.35	0.30	0.50	0.10
Protein	1.00	0.80	0.10	0.01
Ash	0.45	0.40	0.20	0.03
Fat	0.20	0.10	0.10	0.00
Acidity as lactic acid	—*	—*	<2	<1

**not typically determined*

Source: Morrissey, P.A. (1985).

Nutritional Value of Lactose

Lactose is a carbohydrate, and therefore contributes about 4 calories per gram, like other carbohydrates.

Lactose doesn't contribute any other nutrients to the diet; however, it stimulates the intestinal absorption of calcium. The effect is independent of the presence of vitamin D and is exerted on the diffusional component of the intestinal calcium transport system. Since lactose acts on passive calcium absorption, its effect is dependent on calcium intake levels. At low levels, vitamin D-dependent active calcium transport dominates and little effect of lactose is observed. Various mechanisms are responsible for this, one being that the metabolism of lactose by intestinal flora increases the concentration of lactic acid in the intestinal tract. Consequently, pH decreases, improving the solubility and availability of calcium.

Lactose is also capable of forming soluble complexes with calcium, influencing the transport of calcium through the intestinal epithelium membranes in a positive way.

Not only is calcium absorption stimulated by the consumption of lactose, but so is the utilization of phosphorus and various essential trace elements.

Because digestion of lactose is much slower than of glucose or sucrose, lactose is considered relatively safe for diabetics. It does not cause a sharp increase of blood glucose levels like other sweeteners, and therefore, has a nutritional advantage in the diabetic diet.

Physiological Properties of Lactose

Dairy foods are an important source of many nutrients including calcium, high-quality protein, potassium, phosphorus and riboflavin, all essential for development and maintenance of the human body. Recent increases in the recommended amount of calcium required per day for prevention of osteoporosis suggest that its more important than ever that dairy foods remain an important part of the daily diet.

Researchers have studied lactose, the carbohydrate inherent to milk, measuring its benefits and suggesting usage levels for individuals with dietary complications. Results indicate that milk can and should remain an important part of the diet.

In moderation, lactose is safe for diabetics and for those with intolerances. Lactose has also been shown to be safe with respect to dental caries, it has a bifidogenic effect and assists in mineral absorption.

Effect on Diabetics

Dairy products containing lactose are safely consumed by diabetic patients as long as they form a minor part of the diet or recipe. Lactose is digested more slowly than sucrose (half the rate); therefore, is better tolerated by diabetics.

Cariogenicity

Dental caries (tooth decay) is one of the most prevalent, yet preventable, oral health diseases. It is a process considered to be a dynamic equilibrium involving alternating periods of demineralization (release of calcium and phosphate from teeth) and remineralization (replacement of calcium and phosphate).

Foods do not directly cause dental caries, rather, it is a result from complex interactions involving the tooth, oral bacteria and environment. Diet is only one environmental factor in this process; however, dental caries is highly associated with frequent intake of carbohydrates, primarily table sugar (sucrose).

Following the intake of foods containing fermentable carbohydrates, bacteria in dental plaque metabolize the carbohydrate, producing organic acids. When organic acids cause plaque pH to drop from its usual neutrality, demineralization of tooth enamel occurs. Over time, carious lesions can form if preventive measures aren't taken, i.e. brushing with fluoride.

Interestingly, it is not only the amount of fermentable carbohydrate in a food that influences its cariogenicity, but also the food's consistency, how often it is consumed and how long it remains in the mouth. For example, the sugar in dried fruits remains on teeth for a longer period of time than the sugar in chocolate milk. Lactose is also more slowly converted to organic acids than sucrose, minimizing the potential for dental caries.

Research indicates that certain varieties of cheese actually may help protect against dental caries. Studies with laboratory rats, for example, demonstrate that tooth decay decreases when cheese intake follows selected exposure to a high-sugar (sucrose) diet. And in human dental plaque studies, cheeses such as aged Cheddar, Swiss, Blue, Monterey Jack, mozzarella, brie and gouda, as well as American processed, protect against tooth decay. The anticariogenic effect of aged Cheddar cheese has been demonstrated directly in humans who consumed this food immediately following sucrose intake. American processed cheese also has been shown to block a sugar-induced

increase in plaque acidity, thereby reducing tooth enamel lesions and the progression of root caries.

Exactly how cheese protects against tooth decay is unknown, although several possibilities have been suggested. One theory is that cheese may stimulate the flow of alkaline saliva and reduce the number of plaque bacteria. Enamel demineralization can be prevented by stimulation of the production of saliva, which increases plaque pH and the clearance of fermentable carbohydrate from the oral cavity.

Another theory is that calcium and phosphate concentrations in plaque are increased following cheese intake. This increase in minerals reduces the incidence of enamel decalification.

In addition, components in cheese or milk such as protein, lipids, calcium and phosphorus may be partly responsible for the beneficial effects of dairy foods on oral health. For example, lipids in cheese form a protective coating on enamel surfaces, retarding its dissolution. The fatty acids in cheese also have an antibacterial effect against caries.

Australian scientists reported that a protein extracted from milk called casein phosphopeptide helps fight tooth decay. Other researchers have found that milk and the milk protein κ-casein, help prevent cavities by decreasing the formation of plaque.

There is some evidence that chocolate milk may be less likely to contribute to dental caries than sucrose-alone sweetened foods. Cocoa powder has been shown to be noncariogenic. Furthermore, the water-soluble components of cocoa have been found to inhibit plaque accumulation and caries by reducing the biosynthesis of extracellular polysaccharide by selected human plaque-forming microorganisms.

Because chocolate milk is liquid, it is also cleared from the mouth relatively quickly and therefore, may be less cariogenic than candies that stick to the surface of teeth. The moderate amount of sucrose in chocolate milk is no more likely to cause dental caries than other sugars such as fructose in fruits.

Overall, lactose is comparatively safe with respect to dental caries.

Bifidogenic effect

Since lactose is digested rather slowly, a part of the sugar reaches the colon intact and is used as a substrate for beneficial intestinal flora such as bifidobacteria to grow. Growth of bifidum bacteria results in an acid environment, which inhibits the growth of *E. coli* and other putrefying and pathogenic organisms. For infants, this is especially important for resistance against intestinal infections. For both infants and adults, lactose in the diet contributes to the maintenance of stable, healthy intestinal flora.

Mineral Absorption

Because of calcium's protective roles against major diseases such as osteoporosis, hypertension and certain cancers, dairy products have received significant attention in helping individuals obtain adequate amounts of calcium in their diet. Lactose in the diet improves the utilization of calcium and other minerals because of its absorption characteristics. Magnesium, zinc and phosphorus are more efficiently absorbed in the presence of lactose. Other sugars have displayed similar effects but their absorption qualities are minimal because they are digested so quickly in the intestinal tract.

Lactose Intolerance vs. Lactose Maldigestion

Lactose is not readily absorbed by the intestine unless it's first split (hydrolyzed) into its two monosaccharide components—glucose and galactose. The enzyme lactase, which is produced by the epithelial cells of the small intestine, is responsible for breaking down lactose.

All infants, except those with a congenital defect, are born with high levels of the enzyme lactase, enabling them to digest lactose. However, studies show that the maximum activity of the enzyme occurs shortly after birth and declines after the weaning period, after which it remains at a relatively constant level.

Lactose maldigestion is the reduced ability or total inability to hydrolyze lactose in the gastrointestinal tract. The ability to digest lactose is dependent on the lactase activity in the intestine. Various scientific investigations have increased our knowledge about lactose digestion and the incidence of low lactase activity in certain geographic or ethnic groups.

A small number of people with lactose maldigestion experience an upset stomach, gas or diarrhea on certain occasions when they consume lactose-containing foods. The occurrence of these symptoms is called lactose intolerance.

Individuals who consume little or no dairy foods as a result of lactose maldigestion generally have lower intakes of calcium and other nutrients supplied by milk. An inadequate calcium intake increases the risk of osteoporosis, hypertension and perhaps even colon cancer.

Recent research has brought into focus the true extent of lactose maldigestion. Consumers and health professionals have become more aware about lactose maldigestion and its dietary management, learning it's not an all-or-nothing dietary restriction. Total elimination of dairy foods is unnecessary and not recommended.

Several factors influence an individual's tolerance to lactose including the amount of lactose, type of food, whether the lactose-containing food is eaten with a meal, whether the lactose has been fermented or hydrolyzed with an enzyme preparation, and colonic adaptation. Keeping these factors in mind, researchers have developed strategies to allow lactose intolerant individuals to include lactose-containing foods in the diet without experiencing unpleasant symptoms.

Individuals who have low levels of intestinal lactase can consume small amounts of lactose-containing dairy foods, portions that are typical for a single serving. Research has shown that individuals self-described as being severely lactose intolerant are able to tolerate two cups of milk per day when consumed in two widely divided doses with food.

Milk has also been shown to be better tolerated when consumed with a meal. Whole and chocolate milk are the best-tolerated milks because the fat content slows gastric emptying, enabling the small amount of lactase present to have more time to break down the lactose. Furthermore, one's tolerance to lactose can actually be improved by slowly increasing the intake of lactose-containing dairy foods. This is good news for lactose-intolerant consumers because they can still reap all the nutritional benefits of milk, i.e. calcium content.

Functional Properties of Lactose

Lactose provides many functional benefits as a food ingredient. This unique carbohydrate possesses solubility; acts as a bulking agent; acts as a flow agent in dry mixes; has a low level of sweetness yet contributes necessary solids; influences color, flavor and texture; and influences browning reactions.

Solubility

The initial solubility of anhydrous lactose is considerably higher than the value of α lactose monohydrate; however, the final solubility is the same for both types because of the equilibrium reached between the α and β forms after mutarotation. (See Table A-III.) At room temperature this may take several hours before a full equilibrium is reached.

Overall, the solubility of lactose is less than other sugars. (See Table A-IV.) When adding lactose or dairy ingredients with high concentrations of lactose to foods, product developers must be aware of solubility limitations. This comparatively low solubility of lactose limits the amount that can be used in certain applications, but in fact, provides significant advantages in many applications, i.e. instant products and microwaveable foods.

The dissolution speed of lactose depends on the initial solubility as well as other factors like particle size and the structure and mechanical contact between lactose particles and the solvent.

Table A-III

Solubility of Lactose

	Initial (g/100g water at 77°F (25°C))	Final
α lactose monohydrate	8.6	21.6
β lactose	50.0	21.6

Source: USDA Agricultural Handbook No. 8

Table A-IV

Solubility of Various Sugars

	50°F (10°C)	86°F (30°C)	122°F (50°C)
	(g/100g water)		
Fructose	n/a	82	87
Sucrose	66	69	73
Glucose	40	54	70
Galactose	28	36	47
Lactose	13	20	30

Source: USDA Agricultural Handbook No. 8

Functional Properties (continued)

Sweetness

The relative sweetness of lactose is low compared to other sugars. Both the monosaccharides, glucose and galactose, which form the molecular structure of lactose, are much sweeter than lactose itself. (See Table A-V.) β lactose is sweeter than α lactose.

The relatively low sweetness of lactose allows it to be used in higher concentrations in formulations without leading to undesirable high sweetness levels. This permits increased solids contents and achieves modified textural qualities otherwise not possible. It also enables lactose to be used as an energy source in formulations where too much sweetness is undesirable. This is especially important in infant formulas where high sweetness levels could encourage appetite and easily lead to overeating and the development of a taste preference for sweetness.

Synergistic effects of lactose with other food ingredients include sweetness enhancement and sweetness suppression. For example, solutions of lactose and fructose as well as lactose and glucose are slightly less sweet than might be expected from the contribution of the individual carbohydrates.

Table A-V

Relative Sweetness of Some Sugars

Sweetener	Relative Sweetness
Monosaccharides:	
Glucose (2%)	50
Glucose (8-10%)	60-70
Glucose (50%)	90-100
Fructose	115-125
Disaccharides:	
Lactose	15-30
Palatinose (isomaltose)	50
Leucrose (glucose-1,5-fructose)	50
Maltose	50
Lactulose	50-60
Sucrose	100
Polyols (sugar alcohols):	
Lactitol (hydrogenated lactose)	30-40
Mannitol	40
Sorbitol	70
Erythritol	75
Maltitol (hydrogenated maltose)	80
Xylitol (<10%)	85
Xylitol (10%)	100
Xylitol (>10%)	120
Oligosaccharides:	
Lactusucrose	30
Neosugar (fructo-oligosaccharide)	40-60
Soybean oligosaccharide	70
Syrup blends:	
High-fructose corn syrup	100-160
Invert syrup	105

Source: M.A. Godshall (1997).

Also, the amino acid tryptophan enhances the sweetness of lactose and lactose prolongs the duration of sweetness sensation of the sugar alcohol xylitol. Such an effect could be advantageous in the manufacture of chewing gum. On the other hand, sodium chloride in small amounts is known to act as a sweetness enhancer for sucrose but has no effect on the sweetness of lactose. Another synergistic effect is the masking of the bitter aftertaste of saccharin by lactose.

While the higher sweetness level of β lactose would appear to have some advantage in certain products, this is of a transitional nature as some β lactose reverts to α lactose with time, particularly in solution.

The sweetness of lactose solutions can be increased by hydrolysis with β-galactosidase (lactase). This enzyme hydrolyzes the disaccharide into its sweeter monosaccharides.

Adsorption

One of the distinctive features of crystalline lactose is its very low hygroscopicity. Lactose absorbs minimal moisture from the air up to very high levels of relative humidity. (See Table A-VI.) This means that even at high levels of water activity, α lactose monohydrate remains unaffected. This is very important since water activity significantly determines the physical, mechanical and microbiological properties of foods and affects such characteristics as flowability, lumping and cohesion.

Because of its non-hygroscopic qualities and its free-flowing ability in high temperatures and relative humidities, lactose may be used as a carrier for other ingredients such as high-intensity sweeteners, flavors and seasonings. The percentage of lactose in the α monohydrate form may be maximized by controlling crystallizing temperatures when drying high-lactose whey products. "Lactose glass" or "amorphous lactose" is formed from supersaturated solutions of lactose. This material is very hygroscopic and is used in preserving the moisture and tenderness in baked goods and confections.

Table A-VI

Relative Moisture Adsorption of Various Carbohydrates

Anhydrous Material	60% Humidity		100% Humidity
	1 hour	9 days	25 days
	(% moisture absorbed from air at 68°F/20°C)		
Lactose	0.54	1.23	1.38
Cellulose	0.89	5.37	12.57
Maltose	0.80	6.97	18.35
Glucose	0.29	9.00	47.14*
Fructose	0.28	0.63	73.39*
Sucrose	0.04	0.03	18.35*

** These materials continue to absorb moisure after 25 days.*

Source: Foremost Foods Co. (1981).

Viscosity/Texture

Being less sweet than other commercial sugars, lactose can be used to increase viscosity or improve texture without making a food product too sweet. This reduced sweetness permits increased solids contents and achieves modified textural qualities otherwise not possible.

Lactose improves the body, texture, chewiness and shelf life of various candy products, while positively changing the crystallization habits of other sugars present.

Osmotic Pressure

Being less sweet than other commercial sugars, lactose can increase osmotic pressure without making a food product too sweet.

Ingredient Carrier

Lactose's high adsorption capacity for flavors makes it an ideal carrier for spice and seasoning products such as dry soups. It is also commonly used as a carrier for high-intensity sweeteners like aspartame and saccharin.

Studies have confirmed that lactose monohydrate, although showing a lower sorption capacity than anhydrous lactose, is better in retaining flavors, aromas and colors than other sugars. An example of this quality is lactose in tomato sauce, which reduces the acid taste, enhances the tomato flavor and preserves the red color.

Browning

In the formulation of foods, lactose is often used for the purpose of giving the product a brown color. The browning process may be caused by either—carmelization or Maillard reaction.

Carmelization occurs at rather high temperatures and consists of a succession of dehydration, condensation and polymerization reactions. The final products are called melanines because of their brown color. They are mostly water insoluble. Lactose when heated to 302-320°F (150-160°C) turns yellow. It turns brown at 347°F (175°C) with a characteristic odor. Carmelization is an endothermic process that demands a rather high activation energy.

The Maillard reaction occurs between a reducing sugar such as lactose, and the amino group found in proteins. This reaction starts as a condensation of the sugar with the amino group and continues through a series of rearrangements and other reactions, ending with the formation of insoluble melanines. Also as a result of this reaction, volatile aromas are generated. The Maillard reaction can occur at low temperatures and is autocatalytic. It may be accelerated by traces of iron or manganese.

Lactose provides a very good means of inducing controlled browning in foods, especially baked goods and confectionery. In breads, lactose produces a golden brown crust that does not discolor or fade during storage. Since lactose is not fermented by bakers yeast, it remains available for Maillard and carmelization reactions during baking and storage.

Similarly, in the production of caramel-type confections, lactose produces the desirable characteristics of the product as a result of these reactions.

The controlled browning of lactose protein mixtures is highly desirable for the browning of foods in microwaves, where the lower surface temperatures that occur are insufficient for the browning produced in the conventional process.

Instantizing

An expanding area where lactose is useful is in instantizing, or increasing the dispersibility of certain foods. Products are prepared containing 15 to 50% lactose, spray-dried and then instantized by moistening and redrying. This allows some of the lactose to crystallize; the particles then agglomerate, becoming free-flowing and capable of dispersing rapidly.

Flavor Binding

Lactose has a strong affinity for flavorings and flavors. It is able to adsorb and accentuate flavors. Because lactose binds volatile flavor components, there is less flavor loss during processing and storage. This enables a reduction in added flavors, resulting in a possible cost savings.

Table A-VII

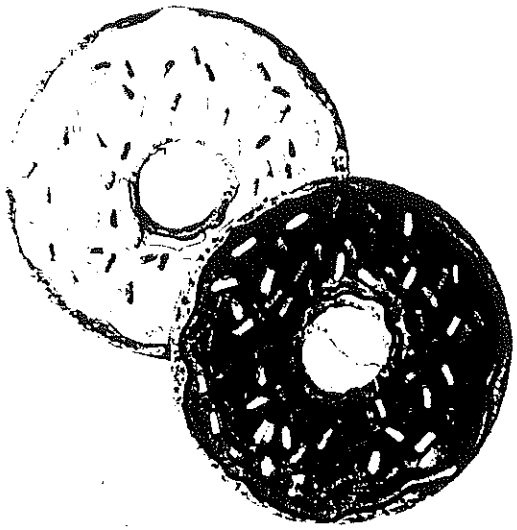
Flavor Binding of Different Sugars

(Adsorbed amounts of tracer flavor components after 24 hour exposure in 10^{-2} mMol/g)

Sugar	Acetone	Ethanol	Propionic acid
Sucrose	0.10	0.15	0.40
Glucose	1.25	0.25	0.50
Lactose	1.90	2.50	1.00

Source: Borculo Whey Products

CHOCOLATE CANDIES
filled with Fondant



Types/Granulations

Lactose

Lactose is a white to creamy white, crystalline powder that has a mildly sweet taste. Crude or refined lactose may be obtained by crystallization either from cheese whey or from whey deproteinized by ultrafiltration or by heat coagulation. These crystallization processes are well established; although a variety of wheys and whey permeates may serve as starting material, sweet whey is preferred.

For many years, only pharmaceutical-grade lactose was produced, but since lactose is now used in an array of products, a variety of grades are now available. Lactose is generally sold as unground or milled to meet supplier or customer standards.

Lactose can exist in a number of different physical forms depending on the method of production. In aqueous solution, lactose exists as an anomeric mixture of α and β forms (38:62). As a solid, it usually crystallizes to the α form as a monohydrate. The anhydrous β form can be obtained only by crystallizing at high temperatures.

Lactose can also be produced in an amorphous state by spray drying. The resultant solid is hygroscopic and is a mixture of α and β lactose. It may contain up to 20% amorphous lactose, showing a water activity of around 0.3.

Commercial anhydrous lactose, which contains about 80% β lactose, shows hardly any hygroscopicity with a water activity value under 0.8.

The following tables provide information on the various types of lactose available for use as food ingredients. Remember to consult your supplier for details about specific lactose types and granulations.

Source

For information about suppliers, including addresses and phone numbers, contact the American Dairy Products Institute, 300 W. Washington St., Chicago, IL 60606. 312/782-4888.

Table 8-1

Physical Properties of Lactose

Properties	α lactose monohydrate	Equilibrium	β lactose anhydride
Molecular weight	360.32		342.30
Melting point	395°F (202°C)		485°F (252°C)
Density	1.55 g/cm³		1.59 g/cm³
Specific optical rotation $[\alpha]_{589}^{20}$	+91.1	+55.5	+33.5
Heat of combustion	16,106 kJ/g		16,465 kJ/g
Specific heat	1,251 J/gK		1,193 J/gK
Heat of solution	-50.24 J/g		-9.62 J/g
Solubility (68°F/20°C)	7.4%	19.1%	48%

Source: Nickerson, T.A. (1974).

Table B-11

Typical Grades and Granulations for Various Lactose Products

Grade	Granulation(*)	Typical particle size distribution (**)
Edible	60 mesh	0-2% on #60 50-60% on #140 65-75% on #200
	80 mesh	1-3% on #80 35-45% on #140 60-70% on #200
	200 mesh	2-5% on #140 3-10% on #200
	325 mesh	0-1% on #200 1-10% on #325
National Formulary	40 mesh	0-2% on #40 75-85% on #140
	80 mesh	0-2% on #80 12-18% on #140 35-45% on #200
	200 mesh	0-1% on #140 1-5% on #200
	325 mesh	0-1% on #140 2-8% on #200
	60 mesh (spray-dried)	0-2% on #60 35-45% on #140 50-70% on #200

Note: (*) Nominal mesh designation
(**) Cumulative values retained on U.S. standard sieves
These granulations serve as a reference. Product developers are encouraged to request from their suppliers the mesh size in order to obtain the desired finished product characteristics.

Source: Foremost Foods Co. (1981).

Table B-III

Typical Bulk Densities for Lactose

Grade	Granulation	Density	
		Poured	Packed
Edible	80 mesh	0.66	0.82
	200 mesh	0.51	0.80
	325 mesh	0.46	0.76
	60 mesh (spray-dried)	0.63	0.73
National Formulary	40 mesh	0.76	0.89
	80 mesh	0.59	0.93
	200 mesh	0.50	0.79
	325 mesh	0.47	0.75
	60 mesh (spray-dried)	0.68	0.76

Source: Foremost Foods Co. (1981).

Lactose Derivatives

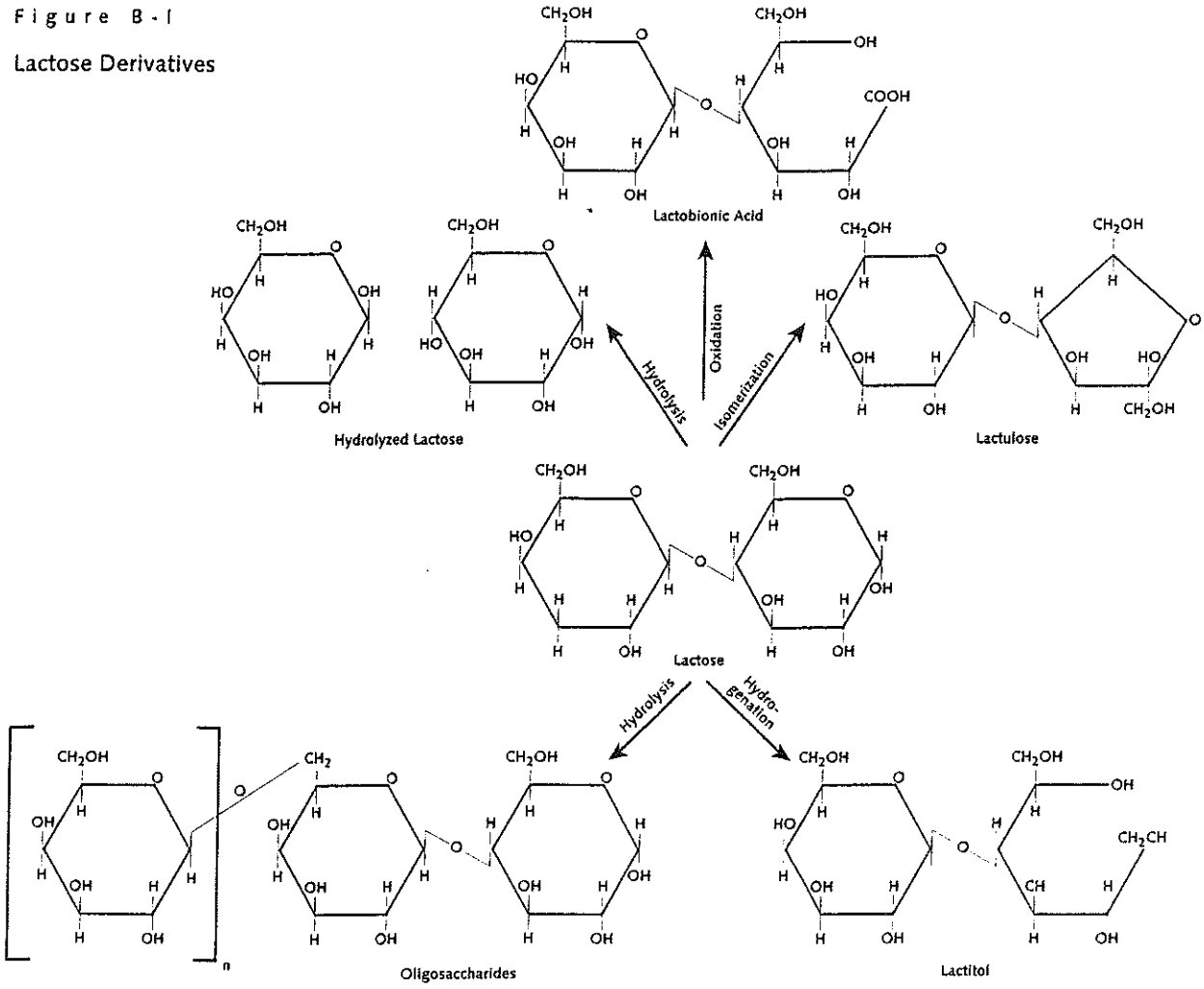
Lactose reacts according to the general rules of carbohydrate chemistry, which includes various types of possible chemical and biochemical reactions. These reactions produce a range of lactose derivatives. (See Figure B-1.)

The range of available lactose derivatives has widely extended applications for lactose ingredients. For example, derivatives can be used in foods formulated for lactose intolerant individuals.

The three major derivatives of lactose, in which the β 1→4 linkage remains intact, are lactulose, formed by isomerization, lactitol, produced by reduction, and lactobionic acid, produced by oxidation. Enzymatic hydrolysis, however, has the greatest impact on the dairy industry, and has led to the commercial availability of lactose-modified milk products in many countries around the world.

Figure B-1

Lactose Derivatives



Lactose Derivatives (continued)

Hydrolyzed Lactose

Lactose is hydrolyzed by the enzyme lactase, which breaks the chemical bond between the glucose and galactose units. As a result, the physical properties change due to the splitting of the disaccharide into two monosaccharides, each with its own specific physical and chemical properties. (See Figure B-I.)

The ice cream industry occasionally finds that in lactose-rich frozen desserts, the lactose tends to crystallize because of its low solubility. This results in a frozen dessert with an undesirable sandy mouthfeel. This can be reduced when part of the lactose is replaced by hydrolyzed lactose. At the same time, the increased sweetness from the hydrolyzed lactose enables a reduction in added sucrose.

The sweetness of hydrolyzed lactose is advantageous in other dairy foods such as flavored milk. Hydrolyzed lactose also has increased flavor enhancing properties.

Hydrolyzed lactose is typically sold in syrup form.

Table B-IV

Properties of Hydrolyzed Lactose as Compared to Lactose
• Increased solubility
• Increased sweetness
• Easier digestion
• More intensive browning action
• Increased flavor enhancement
• Increased osmotic pressure
• More easily fermented

Lactitol

Lactose can be converted into its corresponding sugar alcohol, lactitol, by catalytic hydrogenation. In this reaction, the glucose part of the molecule is reduced through hydrogenation to a sorbitol group. (See Figure B-I.)

Lactitol is readily crystallized as either the mono- or dihydrate, depending on temperature and concentration. Because it is not a reducing sugar, lactitol is very stable under acid and alkaline conditions and at high temperature. It is also non-hygroscopic in contrast to other sugar alcohols. Various grades of lactitol are available for use as a food ingredient.

At room temperature, lactitol attains the solubility of sucrose, so many of its applications are as a sucrose substitute. Its molecular weight is equivalent to that of sucrose so its effect on freezing point and water activity are similar.

Lactitol hydrate has a relative sweetness of about 35% of sucrose. For example, a 17.1% solution has a sweetness equal to that of a 6% sucrose solution.

Compared to lactose, lactitol is highly soluble in water and has a mild, pleasant taste. Due to its low relative sweetness and high solubility, lactitol functions well as a bulking agent in various food formulations. To enhance the sweetness of lactitol, it's recommended that it be used with an intense sweetener such as aspartame or acesulfame K.

Lactitol has a caloric value of two, which is about half that of sucrose. It is also non-cariogenic because it is not readily fermented by oral bacteria.

Clinical trials have shown that lactitol consumption does not increase blood glucose or insulin levels because it is not hydrolyzed or absorbed in the small intestine; therefore, it is an excellent sugar substitute in foods for diabetics. It is, however, fermented by colonic microorganisms, which convert it into volatile fatty acids and carbon dioxide. This limits the amount of the disaccharide that can be used in foods.

Typical applications include bakery products, chewing gum, chocolate, confectionery, frozen desserts, jams and jellies and even some meat products like ham and surimi.

In bakery products, lactitol substitutes one for one with sucrose. It maintains crispiness and provides good texture and shelf life. In chocolate, lactitol doesn't cause any changes in viscosity during storage or melting. It also has good enrobing characteristics and no strong cooling effect. In other confections, lactitol maintains a viscosity and plasticity similar to sucrose. It has good taste and flavor release, as well as good solubility.

Lactitol is most often used in chewing gum where it is applicable as a dusting powder. It's easy to use, has a long shelf life and provides good taste. In frozen desserts, lactitol provides good texture and overrun. It has a depressing effect on freezing point and similar melting characteristics to sucrose. It has application in low-fat formulations.

Lactitol/maltitol syrup blends (70:30) are available for use in hard candy. Blends provide a cost savings in addition to simplifying the production process.

Lactose Derivatives (continued)

Table B-V

Properties of Lactitol
• Good solubility
• Viscosity of aqueous solutions similar to that of sucrose
• Non-hygroscopic
• Melting point 204-220°F (96-105°C)
• Minimal cooling effect
• Degree of sweetness about 0.4 as compared to 1.0 for sucrose
• Suitable for diabetics
• Tooth friendly
• Sweetness profile similar to sugar with no scratchy aftertaste

Table B-VI

Food-grade Lactitol Specifications

Specification	Lactitol monohydrate	Lactitol dihydrate
Molecular weight	362	380
Description	White crystalline powder	White crystalline powder
Taste	Sweet	Sweet
Odor	Odorless	Odorless
Lactitol content	Minimum 97.5%, dry basis	Minimum 97.5%, dry basis
Moisture	4.5-5.5%	9.0-10.5%
Other polyols	Maximum 2.5%	Maximum 2.5%
Reducing sugars	Maximum 0.1%	Maximum 0.1%
Specific rotation $[\alpha]_D^{25}$	+13.5-15.0	+13.5-15.0
pH of 10% solution	4.5-8.5	4.5-8.5
Chloride	Maximum 30 ppm	Maximum 30 ppm
Sulfate	Maximum 30 ppm	Maximum 30 ppm
Ash content	Maximum 0.1%	Maximum 0.1%
Heavy metals	Maximum 10 ppm	Maximum 10 ppm
Arsenic	Maximum 1 ppm	Maximum 1 ppm
Nickel	Maximum 1 ppm	Maximum 1 ppm

Source: Nickerson, T.A. (1974).

Lactulose

Lactulose is a disaccharide composed of galactose and fructose. It is obtained from lactose by isomerization of its glucose moiety. (See Figure B-I.)

Until recently, the primary application for lactulose had been medicinal. Lactulose reduces serum cholesterol and paradontosis prophylaxis. However, product developers have identified new applications in infant formula, baby food, sugar substitutes, confectionery, soft drinks, yogurt and diabetic foods.

Recent research indicates that the addition of lactulose has a positive effect on the growth of bifidobacteria in the intestine. For this reason, in some sectors of the food industry it is termed a nutraceutical ingredient.

Lactobionic Acid

Lactobionic acid is not normally found in nature but may be readily produced from lactose by specific oxidation of the free aldehyde group. It is used as an acidulant and as a complexing agent for metal ions in the food and pharmaceutical industries. (See Figure B-I.)

Table B-VII

Food-grade Lactulose Specifications

Specification	Lactulose
Molecular weight	342
Color	White, odorless crystalline powder or yellowish liquid syrup
Taste	Sweet (0.5 times as sweet as sucrose; 1.5 times as sweet as lactose)
Solubility	Water soluble

Source: Strohmaier, W. (1996).

Table B-VIII

Crystalline Lactulose Trihydrate Specifications

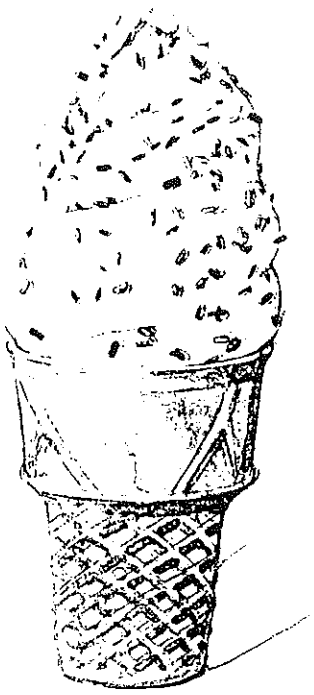
Specification	Lactulose Trihydrate
Lactulose	86.4%
Moisture	13.6%
Melting point	155°F (68°C)
Solubility (59°F/15°C)	53%
Heat of solution	34 kJ/mol
Storage	At or below ambient temperatures

Source: Tamura, T., et al. (1993).

Oligosaccharides

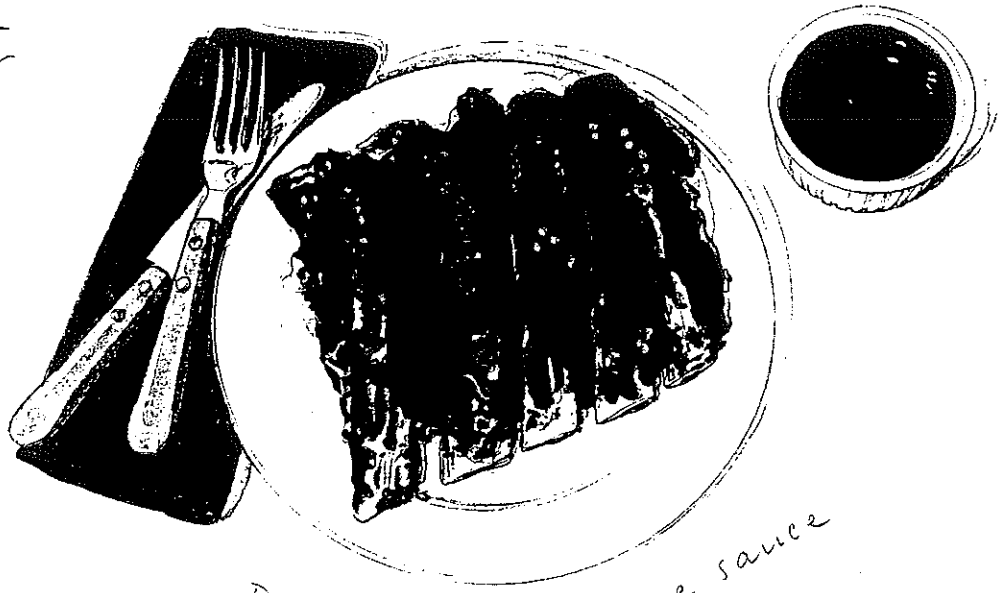
Using similar types of β-galactosidase as for the hydrolysis of lactose, galacto-oligosaccharides can be produced by enzymatic conversion of lactose. (See Figure B-I.) Galacto-oligosaccharides are not digested by intestinal enzymes, and therefore reach the colon undigested. In the colon, bifidobacteria and lactobacilli ferment galacto-oligosaccharides, improving the composition of colonic microflora.

Applications include use as a food ingredient for bulking and stabilizing or for high biological value, i.e. bifidogenic activity. The main impacts are quality improvement, texture and structure, shelf life improvements and nutritional/dietary aspects.

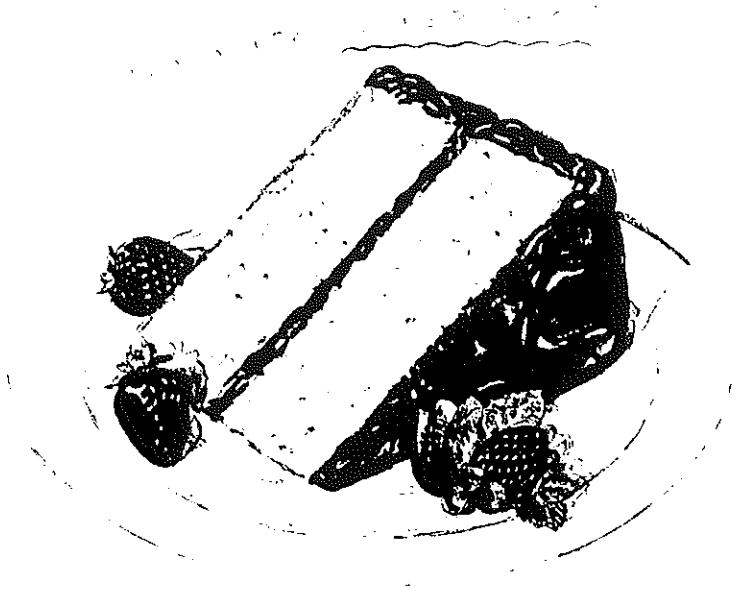


Frozen Dessert

Applications

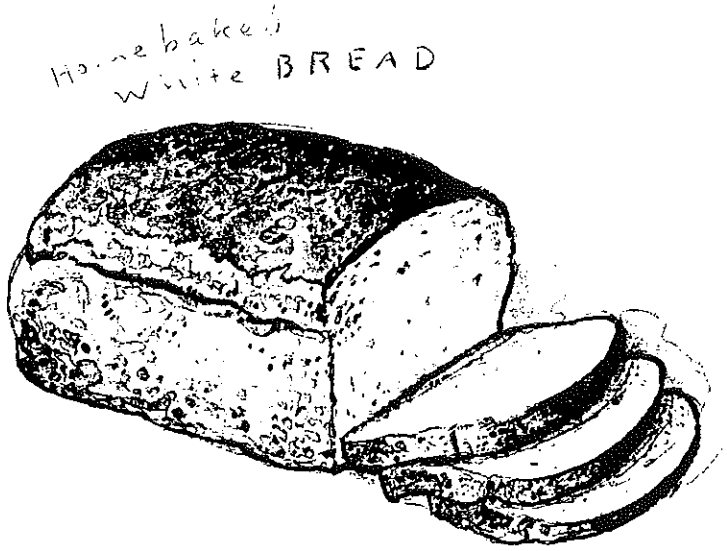


RIBS with barbecue sauce



Applications

Bakery Products



Why Use Lactose in Bakery Products

Because of lactose's low sweetness level and low solubility, many product developers are not aware of its food ingredient capabilities. However, the benefits derived in using lactose are a direct result of its characteristics. Today we see many diverse food applications because of these properties, which include its relative sweetness, browning ability, protein stabilizing qualities, alteration of crystallization, flavor enhancement, selective fermentation and nutritive qualities.

Lactose and lactose derivatives assist product developers in the formulation of a variety of bakery products.

The bakery industry uses lactose to replace sucrose for a variety of functional benefits. (See Table C-I-1.) Lactose's physical and chemical properties offer many benefits as compared to other sugars in the manufacture of bakery products. These include its low relative sweetness, browning ability, emulsifying action, moisture retention, non-hygroscopicity, not being affected by yeast and boosting of color. When replacing sucrose (up to 50%), lactose can contribute to improved crumb texture and freshness, increased volume, reduced fat levels, improved gas retention and enhanced flavor.

The addition of lactose shortens proofing times, especially where the overall level of sugar is high. Doughs made with lactose show a tendency to rise faster during the initial stages of proofing and show improved stability and gas retention.

Lactose influences and enhances the controlled browning of bakery goods leading to shorter baking times and lower temperatures in order to achieve even, stable, golden brown colors. This is a particular benefit in products targeted for microwave finishing.

Lactose has unique volatile flavor-binding and enhancing properties, which are particularly useful in bakery products with delicate flavors. Lactose has a strong affinity for flavorings and flavors. It is able to adsorb and accentuate flavors. Because lactose binds volatile flavor components, there is less flavor loss during processing and storage. This enables a reduction in added flavors, resulting in a possible cost savings.

Lactose extends shortening in bakery products, enabling a fat reduction in certain recipes. For example, in sponge cake, lactose can replace up to 33% of the original fat.

Research also indicates that when lactose is used in the production of sponge and yellow cakes, cakes have a darker crust color as compared to control cakes. A softer crumb in sponge cakes is observed when a higher level of lactose is used and yellow cakes become more fragile as the amount of lactose increases. It is important to adhere to replacement levels to prevent any reduction in quality, and hence shelf life.

Table C-I-1

Typical Uses of Lactose in Bakery Products

Product	Lactose level	Benefits gained by using lactose
Specialty breads and rolls	3-4% (based on weight of flour)	• Produces golden brown color that does not turn dull in storage • Improves softness • Reduces shortening requirements by as much as 50% by replacing up to 50% of the sucrose
Sweet rolls and pastry	4-5% (based on weight of flour)	• Produces golden brown color • Enhances flavor • Improves softness and tenderness • Reduces shortening and sucrose requirements
Pie crusts and shells	8% (based on weight of flour)	• Results in shorter, flakier, more tender crusts • Imparts uniform, bright orange-brown color to both top and bottom crusts • Increases mixing tolerances • Provides greater latitude as to types of flour used • Extends shortening content. Shortening can generally be reduced by about 5% • Distributes fat ideally with minimum mixing • Retards sogginess
Cakes and muffins	10-15% replacement of other sugars	• Results in maximum tenderness without excessive sweetness • Produces golden brown, flavorful crust • Improves cake volume • Accentuates flavors, i.e. spice, coconut, vanilla, chocolate, etc.
Cookies	3-4% (based on weight of flour)	• Increases mixing tolerances • Eases release from rotary dies • Assures ideal fat distribution • Sharpens and enhances flavor • Controls sweetness level • Produces optimum tenderness and ideal crust colors • Produces richer tasting cookies

Source: Foremost Foods Co. (1981).

Cake

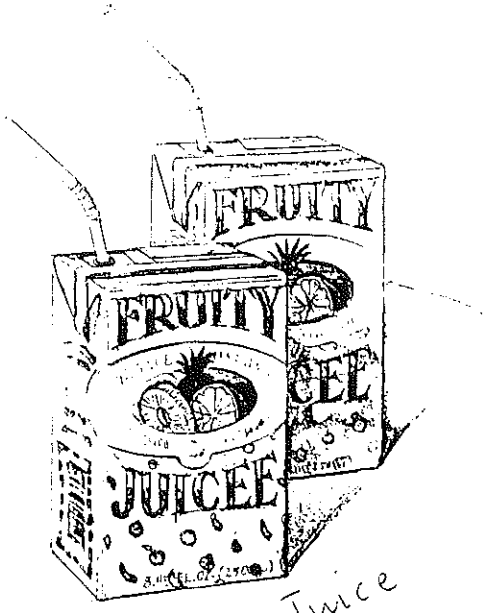
Ingredient	Usage Level (%)
Sugar	26.00
Water	25.00
Cake flour	24.00
Eggs	8.00
Shortening	7.00
Lactose	5.00
Nonfat dry milk	3.00
Baking powder	1.50
Salt	0.50
	100.00

Sponge Cake

Ingredient	Usage Level (%)
Water	35.00
Cake Flour	25.90
Sugar	24.90
Lactose	6.00
Eggs, whole solids	3.90
Baking powder	1.60
Nonfat dry milk	1.60
Emulsifier	1.00
Vanilla	0.10
	100.00

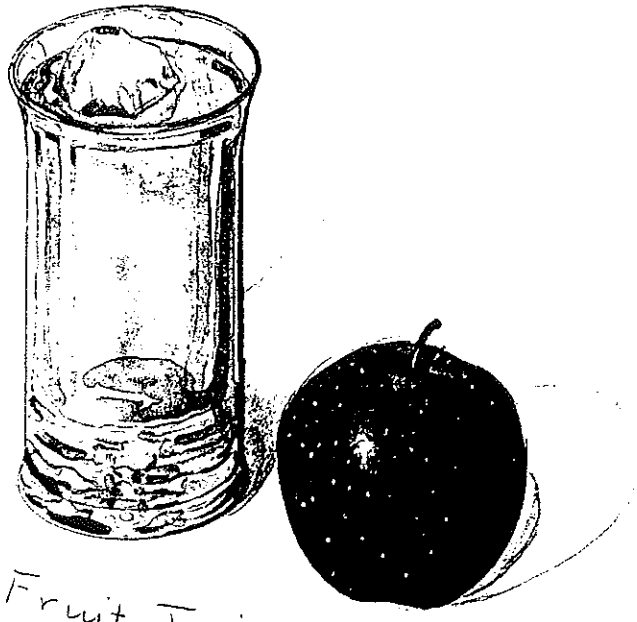
Yellow Cake

Ingredient	Usage Level (%)
Water	29.00
Sugar	25.00
Cake flour	23.30
Shortening	8.60
Lactose	6.00
Eggs, whole solids	4.70
Baking powder	1.30
Salt	0.70
Nonfat dry milk	0.60
Emulsifier	0.60
Flavoring	0.10
Egg, liquid color	0.10
	100.00



Applications

Beverages



Why Use Lactose in Beverages

Because of lactose's low sweetness level and low solubility, many product developers are not aware of its food ingredient capabilities. However, the benefits derived in using lactose are a direct result of its characteristics. Today we see many diverse food applications because of these properties, which include its relative sweetness, browning ability, protein stabilizing qualities, alteration of crystallization, flavor enhancement, selective fermentation and nutritive qualities.

Lactose and lactose derivatives assist product developers in the formulation of a variety of beverages.

Lactose has been used in the manufacture of beer because it is not fermented by the yeast. It remains in the finished product, increasing viscosity and improving mouthfeel and flavor.

In juice beverages, lactose is used to enhance flavor and provide stability. Hydrolyzed lactose syrups increase the sweetness of fruit-containing beverages. Lactose has a strong affinity for flavorings and flavors. It is able to adsorb and accentuate flavors. Because lactose binds volatile flavor components, there is less flavor loss during processing and storage. This enables a reduction in added flavors, resulting in a possible cost savings.

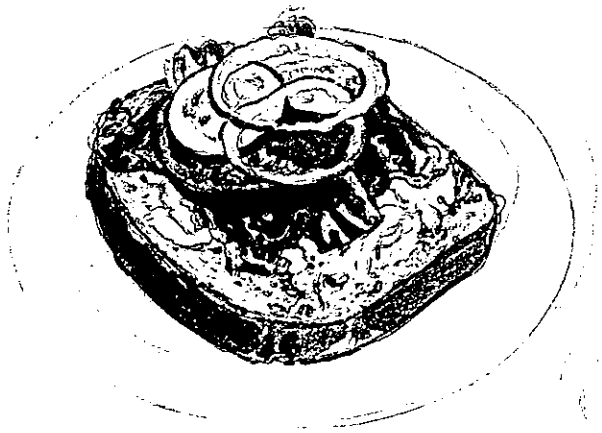
Fruit Juice Drink

Ingredient	Usage Level (%)
Apple juice	50-65%
Passion fruit juice	3-5%
White grape juice	10-20%
Lemon juice	10-20%
Hydrolyzed lactose	11-17%
Flavor	
Water	
Final pH 4.3	

Applications

Condiments

Salad Dressings



Open face SANDWICH with Mayonnaise

Why Use Lactose in Condiments

Because of lactose's low sweetness level and low solubility, many product developers are not aware of its food ingredient capabilities. However, the benefits derived in using lactose are a direct result of its characteristics. Today we see many diverse food applications because of these properties, which include its relative sweetness, browning ability, protein stabilizing qualities, alteration of crystallization, flavor enhancement, selective fermentation and nutritive qualities.

Lactose and lactose derivatives assist product developers in the formulation of a variety of condiments.

Lactose is added to condiments to improve flavor. Lactose has a strong affinity for flavorings and flavors. It is able to adsorb and accentuate flavors. Because lactose binds volatile flavor components, there is less flavor loss during processing and storage. This enables a reduction in added flavors, resulting in a possible cost savings.

Lactose is also added for product stability. Lactose has a stabilizing effect on the proteins against flocculation and syneresis, particularly during pH reduction and pasteurization.

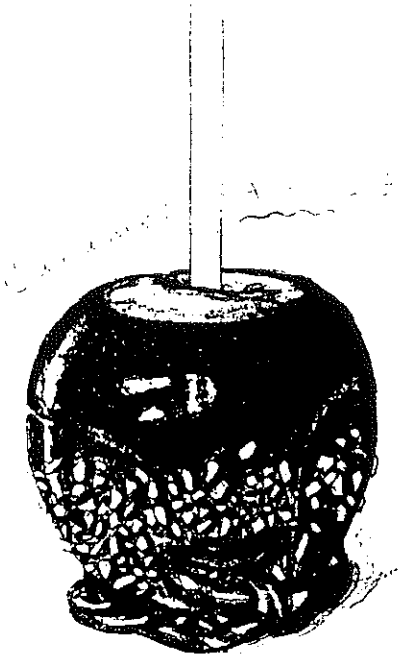
Typical applications include salad dressing, soy sauce, mayonnaise, ketchup and barbecue sauce.

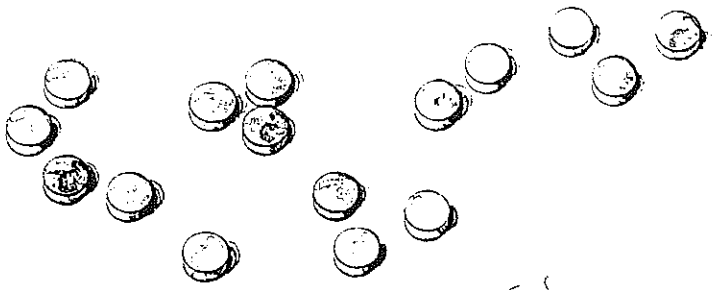
French Dressing

Ingredient	Usage Level (%)
Vegetable oil	62.00
Vinegar (50 grain)	32.00
Salt	1.50
Lactose	1.40
Sugar	1.20
Powdered garlic	0.70
Powdered onion	0.60
Paprika	0.60
	100.00

Garlic Dressing

Ingredient	Usage Level (%)
Salad oil	71.00
Tomato juice	12.00
Vinegar (50 grain)	12.00
Salt	2.00
Lactose	1.00
Powdered garlic	0.50
Mustard flour	0.50
Pepper oleoresin	0.50
Celery seed	0.50
	100.00



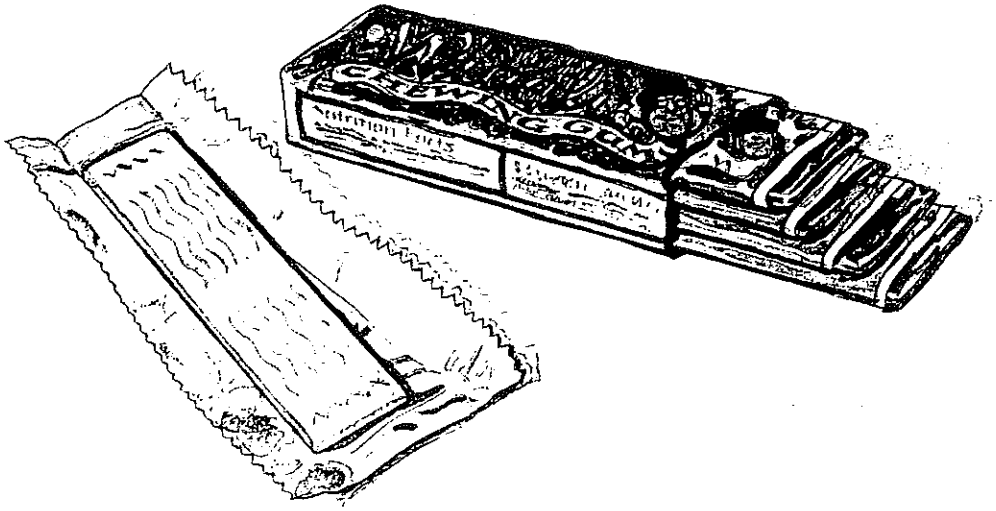


Tabletted CANDIES

Applications

Confections

Chewing Gum



Why Use Lactose in Confections

Because of lactose's low sweetness level and low solubility, many product developers are not aware of its food ingredient capabilities. However, the benefits derived in using lactose are a direct result of its characteristics. Today we see many diverse food applications because of these properties, which include its relative sweetness, browning ability, protein stabilizing qualities, alteration of crystallization, flavor enhancement, selective fermentation and nutritive qualities.

Lactose and lactose derivatives assist product developers in the formulation of a variety of confections.

Milk products are used as a raw material in a variety of confections, contributing to overall flavor, color and texture. Thus, milk sugar has an important role in the formulation of many confections.

The relatively low sweetness level of lactose can prevent excessive sweetness in finished candy. This is accomplished by replacing part of the sucrose with lactose. Replacements of 15-20% have been achieved in the production of nougat, chewing gum and fondants.

Lactose is also a very effective flavor binder, emphasizing and enhancing various confection flavors. Lactose is able to hold odors and pigments that are absorbed on its surface as crystals form. They are retained there until the lactose is dissolved during consumption. Because lactose binds volatile flavor components, there is less flavor loss during processing and storage. This enables a reduction in added flavors, resulting in a possible cost savings.

Because lactose caramelizes at higher temperatures than other sugars, its functionality in achieving color prominence in caramels is very good. It also enhances the milky caramel flavor. Studies show that excellent caramels can be made using 5-10% hydrolyzed lactose.

Lactose also increases moisture retention and improves whipability in marshmallow products by replacing as little as 10% of sucrose with lactose.

Tabletted candies made with lactose show free-flow characteristics. The small crystal size of fine mesh lactose displays rapid solubility and eliminates the possibility of the product being course or grainy.

High boilings, which are a mixture of sucrose and glucose syrup to which color, flavor and sometimes citric acid have been added, tend to pick up moisture from the environment because of their amorphous nature. Replacing some (about 4%) of the sucrose with lactose reduces moisture uptake, decreasing the tendency for the high boiling to stick to the wrapper.

In wine gums, substituting up to 30% of sucrose with lactose results in a product with improved taste and flavor. It is not excessively sweet, like traditional wine gums. The lactose prevents premature drying and crust formation, while maintaining a chewy product, contrary to the dry, tough standard.

Licorice gums made by substituting 30% of sucrose with lactose have been valued better than the standard. They have a short, soft, easily chewable and non-sticky texture.

The limit of lactose as a sucrose replacer is illustrated in Table C-IV-1. Use in excess of these percentages can reduce quality.

In the manufacture of milk chocolate, lactose can improve the flavor, texture, viscosity and cost. Lactose may be added to milk chocolate by direct substitution for sucrose.

Table C-IV-2 suggests various replacement levels of lactose for sugar or nonfat dry milk. A 5-10% substitution of sucrose by lactose has been shown to be feasible. Lactose may substitute for nonfat dry milk. As a result, total sugar increases while nonfat dry milk decreases. This is done in chocolate in order to take advantage of the cost difference between lactose and nonfat dry milk. Lactose addition is limited by quality degradation in the finished product. These formulations are dependent on the type of product and individual processes.

Table C-IV-1

Sucrose Replacement Limits in Confections

Confection	Lactose/lactose + sucrose (%)
Pectin jellies	10
Licorice (English-style)	5
Licorice (Continental-style)	10
Wine gums	<10
Starch-based pastilles	10
Marshmallows	10
Ungrained nougat	15-20
Pulled chews	10-15
Chewing gum	15
Fondants	20
Marzipan	25
Fudge	25
Lozenges	35

Source: Association of Lactose Manufacturers (1988).

Table C-IV-2

Lactose Substitution in Milk Chocolate

Ingredient	Control	Substitute #1	Substitute #2
Cocoa mass	24	24	24
Cocoa butter	11	11	11
Nonfat dry milk	16.8	12.7	12.7
Butterfat	7.2	7.2	7.2
Sucrose	36	36	31
Lactose	—	4.1	9.1
Lecithin	0.2	0.2	0.2
Vanillin	0.012	0.012	0.012

Substitute #1: 25% of the nonfat dry milk is replaced by lactose
Substitute #2: 25% of the nonfat dry milk and 14% of the sucrose is replaced by lactose

Source: Association of Lactose Manufacturers (1990).

Table C-IV-3

Lactose Formulations for Various Chocolate Confections

Ingredient	Whole milk	Milk	Bitter	White
Cocoa mass	24	12	33	—
Cocoa butter	11	19	20	28
Dry whole milk	24	20	—	28
Sucrose	36	42	42	41
Lactose	5	5	5	5
Anhydrous milkfat	—	1.5	—	—
Lecithin	0.2	0.35	0.15	0.2
Vanillin	0.012	0.04	0.015	0.010

Source: Association of Lactose Manufacturers (1990).

Table C-IV-4

Typical Uses of Lactose in Confections

Product	Lactose level	Benefits gained by using lactose
Icings and frostings	15-20% replacement of sugars	• Prevents excessive sweetness • Produces and retains richer flavor • Produces smooth, non-grainy body that remains so in storage • Distributes color pigment evenly and thoroughly • Preserves moistness in long storage

Source: Foremost Foods Co. (1981).

Fondant

Ingredient	Usage Level (%)
Sucrose	46.70
Water	19.20
Lactose	18.20
Glucose syrup (42 DE)	15.90
	100.00

High Boilings

Ingredient	Usage Level (%)
Sucrose	44.00
Glucose syrup (42 DE)	37.10
Water	15.50
Lactose	2.30
Citric acid	0.87
Flavor	0.12
Color (10% solution)	0.11
	100.00

Licorice

Ingredient	Usage Level (%)
Glucose syrup (42 DE)	31.40
Sucrose	21.40
Water	17.47
Lactose	9.20
Modified starch	6.55
Gelatin	4.37
Licorice powder	4.37
Sorbitol syrup (70% solids)	3.49
Caramel color	1.75
	100.00

Sugarless Milk Chocolate

Ingredient	Usage Level (%)
Lactitol	47.09
Cocoa butter	26.50
Lactose-reduced dry milk	14.00
Cocoa liquor	12.00
Lecithin	0.30
Aspartame	0.09
Vanillin	0.02
	100.00

Sugarless Gianduja Chocolate

Ingredient	Usage Level (%)
Lactitol	38.60
Cocoa butter	27.00
Hazelnut paste	18.00
Milk protein	8.60
Cocoa powder	4.00
Milkfat	3.50
Lecithin	0.23
Aspartame	0.07
	100.00

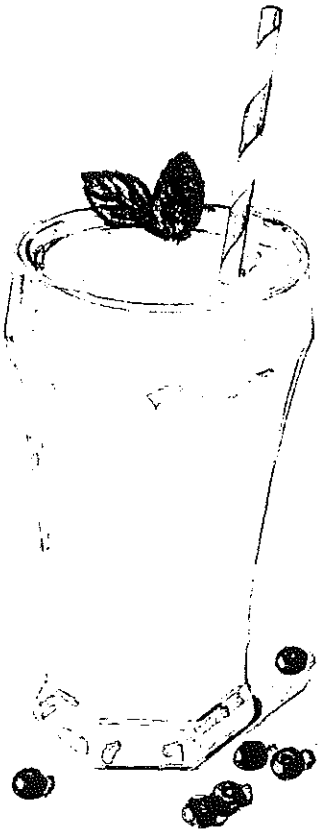
Wine Gum

Ingredient	Usage Level (%)
Glucose syrup (42 DE)	36.40
Water	22.20
Sucrose	20.00
Gelatin (100 Bloom)	12.70
Lactose	8.70
Citric acid	as needed
Flavor	as needed
Color	as needed
	100.00

FLAN
with caramel sauce

Applications

Dairy Foods



Vanilla
YOGHURT
Drink

Why Use Lactose in Dairy Foods

Because of lactose's low sweetness level and low solubility, many product developers are not aware of its food ingredient capabilities. However, the benefits derived in using lactose are a direct result of its characteristics. Today we see many diverse food applications because of these properties, which include its relative sweetness, browning ability, protein stabilizing qualities, alteration of crystallization, flavor enhancement, selective fermentation and nutritive qualities.

Lactose and lactose derivatives assist product developers in the formulation of a variety of dairy foods.

Lactose has a strong affinity for flavorings and flavors. It is able to adsorb and accentuate flavors. Because lactose binds volatile flavor components, there is less flavor loss during processing and storage. This enables a reduction in added flavors, resulting in a possible cost savings.

Table C-V-1

Typical Uses of Lactose in Dairy Food

Product	Lactose Level	Benefits gained by using lactose
Custards and creams	15-20% replacement of other sugars	• Controls sweetness • Produces smooth, tender and even texture • Enhances flavor

Source: Foremost Foods Co. (1981).

The ice cream industry occasionally finds that in lactose-rich frozen desserts, the lactose tends to crystallize because of its low solubility. This results in a frozen dessert with an undesirable sandy mouthfeel. This can be reduced when part of the lactose is replaced by hydrolyzed lactose. At the same time, the increased sweetness from the hydrolyzed lactose enables a reduction in added sucrose.

The sweetness of hydrolyzed lactose is also advantageous in other dairy foods such as flavored milk. In addition to increased sweetness, there is also the benefit to be gained from the increase in flavor enhancing properties of hydrolyzed lactose.

Frozen Dessert

Ingredient	Usage Level (%)
Water	51.40
Cream (41% fat)	24.40
Fructose	8.50
Corn syrup solids (24 DE)	5.00
Lactose	4.50
Whey protein concentrate (34%)	3.80
Caseinate	2.00
Stabilizer/emulsifier	0.40
	100.00

Sherbet

Ingredient	Usage Level (%)
Sugar	17.00
Corn syrup solids (36 DE)	9.60
Lactose	5.00
Reduced-minerals whey	3.50
Butterfat	1.50
Stabilizer	as needed
Flavor	as needed
Water	as needed

Yogurt Drink

Ingredient	Usage Level (%)
Water	89.60
Nonfat dry milk	6.24
Lactose	2.28
Whey protein concentrate (75-79%)	1.88
Yogurt culture	as needed
Sweetener	as needed

Applications

Dry Mixes

Hot Cocoa Mix

Why Use Lactose in Dry Mixes

(beverages, flavors, sauces, soups, seasonings, spices, sweeteners, etc.)

Because of lactose's low sweetness level and low solubility, many product developers are not aware of its food ingredient capabilities. However, the benefits derived in using lactose are a direct result of its characteristics. Today we see many diverse food applications because of these properties, which include its relative sweetness, browning ability, protein stabilizing qualities, alteration of crystallization, flavor enhancement, selective fermentation and nutritive qualities.

Lactose and lactose derivatives assist product developers in the formulation of a variety of dry mixes.

Lactose's low hygroscopicity optimizes its use as a filler, free-flowing agent and a stratification retardant. Because lactose has no characteristic flavor of its own other than its relatively low sweetness, it can easily be used to increase solids without influencing flavor. It is an ideal carrier for flavors and seasonings. It also acts as a carrier for high-intensity sweeteners, food colors and vitamin and mineral pre-mixes.

Lactose has a strong affinity for flavorings and flavors. It is able to adsorb and accentuate flavors. Because lactose binds volatile flavor components, there is less flavor loss during processing and storage. This enables a reduction in added flavors, resulting in a possible cost savings.

An expanding area where lactose is useful is in instantizing, or increasing the dispersibility of dry mixes. Products are prepared containing 15% to 50% lactose, spray-dried and then instantized by moistening and redrying. This allows some of the lactose to crystallize; the particles then agglomerate, becoming free-flowing and capable of dispersing rapidly.

Table C-VI-1

Typical Applications of Lactose in Dry Mixes	
Coffee creamers	Flavors
Soups	Spice blends
Instant potatoes	MSG extenders
Salad dressings	Food colors
Sauces	Low-calorie sweeteners
Gravy mixes	Instantizing aids
Soft drinks	

Source: Foremost Foods Co. (1981).

French Onion Soup Mix

Ingredient		Usage Level (%)
Dehydrated chopped French onion		62.00
French onion powder		16.00
Seasoning mix		22.00
Salt	70.30	
Lactose	10.10	
Monosodium glutamate	10.00	
Powdered parsley	3.30	
Dried food yeast	2.50	
Paprika	2.50	
Black pepper	1.25	
Caramel coloring	0.05	
	100.00	
		100.00

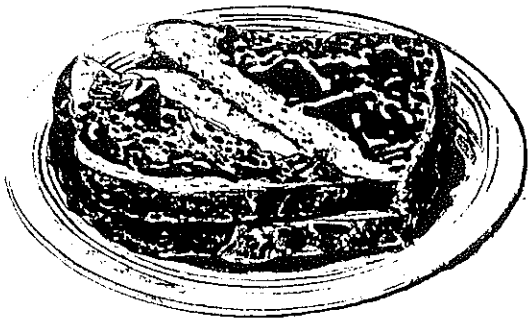
Onion Soup Mix

Ingredient		Usage Level (%)
Dehydrated chopped onion		57.0
Powdered onion		15.0
Seasoning mix		28.0
Salt	59.68	
Monosodium glutamate	18.46	
Lactose	15.00	
Smoked yeast powder	3.35	
Paprika	2.54	
Black pepper	0.64	
Ground sweet basil	0.33	
	100.00	
		100.00

Saccharin Dry Mix

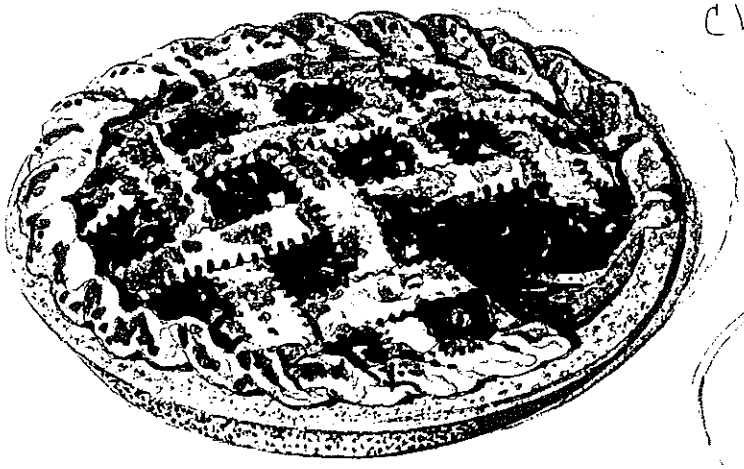
Ingredient	Usage Level (%)
Lactose	96.00
Saccharin	4.00
	100.00

Grape
JELLY

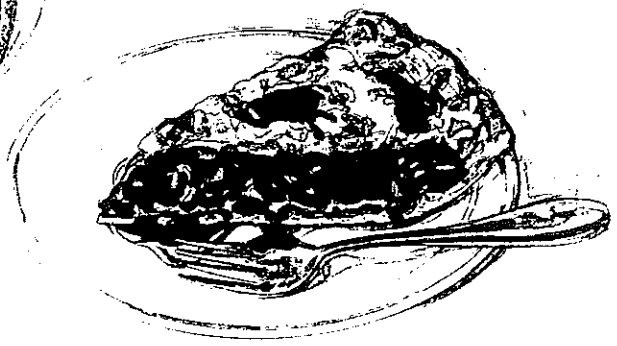


Applications

Fruits and Vegetables



Cherry pie
FILLING



Why Use Lactose in

Fruits and Vegetables

(canned, fillings, preserves, etc.)

Because of lactose's low sweetness level and low solubility, many product developers are not aware of its food ingredient capabilities. However, the benefits derived in using lactose are a direct result of its characteristics. Today we see many diverse food applications because of these properties, which include its relative sweetness, browning ability, protein stabilizing qualities, alteration of crystallization, flavor enhancement, selective fermentation and nutritive qualities.

Lactose and lactose derivatives assist product developers in the formulation of a variety of fruits and vegetables.

In preserves and fruit products like pectin jellies, the lower sweetness level of lactose has a distinct advantage in acting as a sucrose replacer because it still has the bulking and osmotic pressure effect associated with sucrose. Thus taste, flavor and consistency can be maintained. Recommended replacement levels are 6-8%. Use at this level does not affect the consistency, gel strength or color of the preserve or fruit product.

Table C-VII-1

Typical Uses of Lactose in Fruit Products

Product	Lactose level	Benefits gained by using lactose
Pie fillings	15-20% replacement of other sugars	• Accentuates flavors, especially those of fruits and berries • Prevents excessive sweetness • Preserves natural colors of fruits and berries

Source: Foremost Foods Co. (1981).

In canned vegetables, lactose is a potential firming agent for texture improvement. An 8% or higher concentration of lactose in the brine is necessary for any texture improvements. At these concentrated levels, lactose may also improve the taste of the canned vegetables.

Lactose has a strong affinity for flavorings and flavors. It is able to adsorb and accentuate flavors. Because lactose binds volatile flavor components, there is less flavor loss during processing and storage. This enables a reduction in added flavors, resulting in a possible cost savings.

Pectin Jelly

Ingredient	Usage Level (%)
Sucrose	33.70
Glucose syrup (42 DE)	32.80
Water	22.50
Lactose	9.80
High-methoxyl pectin	1.20
Citric acid	as needed
Color	as needed
Flavor	as needed
	100.00

Dry Infant Formula

Concentrated LIQUID

Applications

Infant Foods

Ready-to-use

Why Use Lactose in Infant Foods

Because of lactose's low sweetness level and low solubility, many product developers are not aware of its food ingredient capabilities. However, the benefits derived in using lactose are a direct result of its characteristics. Today we see many diverse food applications because of these properties, which include its relative sweetness, browning ability, protein stabilizing qualities, alteration of crystallization, flavor enhancement, selective fermentation and nutritive qualities.

Lactose and lactose derivatives assist product developers in the formulation of a variety of infant foods. For that matter, the major use for lactose is in the production of infant formulas.

Lactose is the vital source of energy for the newborn child. After birth, it takes several days before the energy from fats and proteins becomes available. Lactose is slowly hydrolyzed in the intestines, generating a gradual and prolonged energy supply at a constant blood glucose level in the period between feedings.

Because the lactose content of human milk exceeds cows milk (7% vs. 4.6%), it is necessary to fortify cows milk-based breast milk replacers to comparable levels.

Lactose also helps to establish a favorable environment in the intestine, resulting in the development of a lactic acid flora that helps inhibit the growth of pathogenic microorganisms. At the same time, lactose has a positive effect on intestinal passive calcium absorption. Also, being a mild sweetening agent, lactose helps stimulate the baby to drink milk.

Demineralized Whey-based Infant Formula

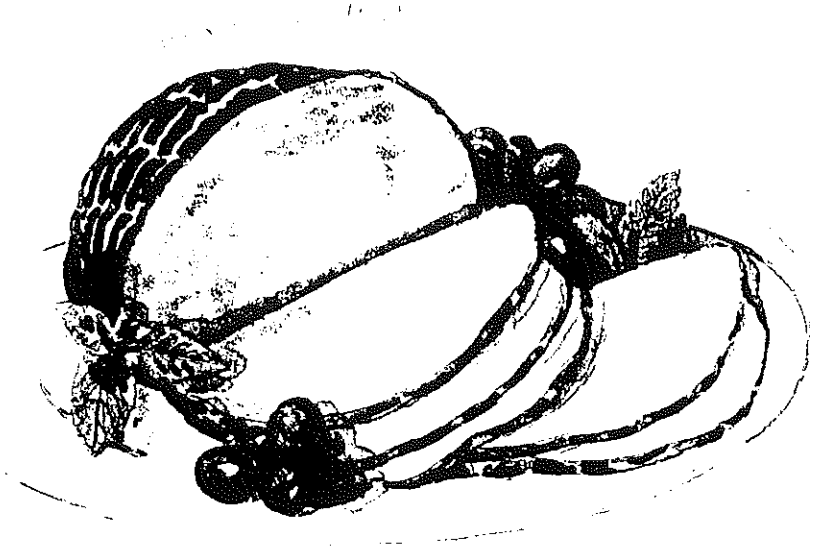
Ingredient	Usage Level (%)
Reduced-minerals whey	43.00
Fat blend	28.00
Nonfat dry milk	16.00
Lactose	11.30
Vitamins and minerals	1.20
Lecithin	0.50
Water	as needed

Milk-based Infant Formula

Ingredient	Usage Level (%)
Lactose	38.30
Nonfat dry milk	34.00
Fat blend	27.00
Lecithin	0.50
Vitamins and minerals	0.25
Water	as needed

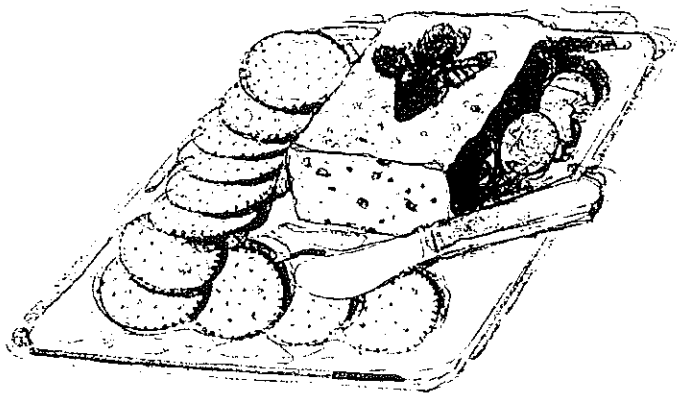
Whey Protein-based Infant Formula

Ingredient	Usage Level (%)
Lactose	37.00
Fat blend	27.00
Whey protein concentrate (34%)	18.50
Nonfat dry milk	16.00
Vitamins and minerals	1.00
Lecithin	0.50
Water	as needed

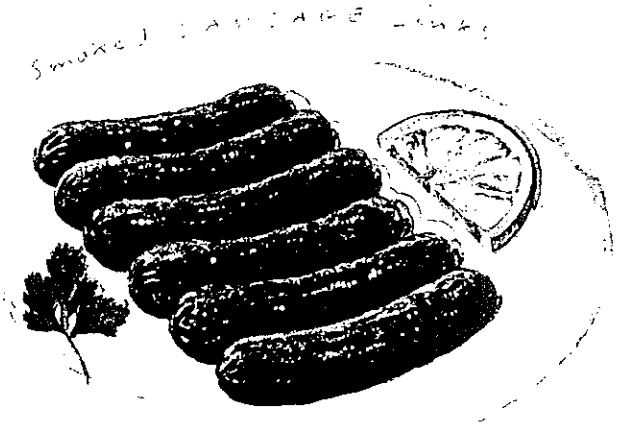


Applications

Meat Products



Liver Pâté



Why Use Lactose in Meat Products

Because of lactose's low sweetness level and low solubility, many product developers are not aware of its food ingredient capabilities. However, the benefits derived in using lactose are a direct result of its characteristics. Today we see many diverse food applications because of these properties, which include its relative sweetness, browning ability, protein stabilizing qualities, alteration of crystallization, flavor enhancement, selective fermentation and nutritive qualities.

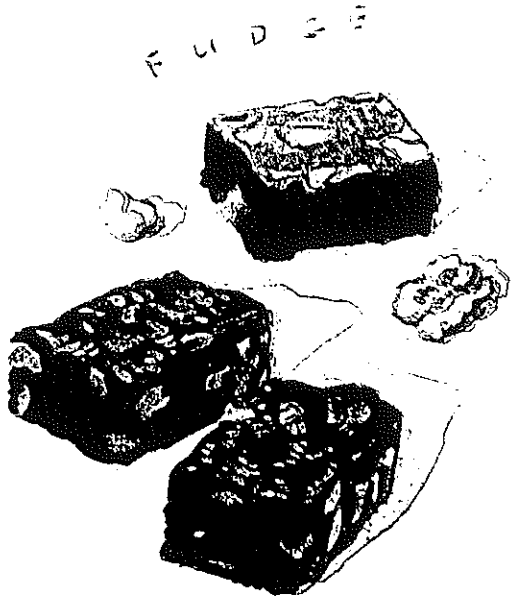
Lactose and lactose derivatives assist product developers in the formulation of a variety of meat products.

Lactose enhances the color intensity and stability of several meat products. It is also known to brighten and preserve color. In sausage and meat products, the addition of lactose results in controlled browning due to the Maillard reaction. This is especially important during heat treatments like frying or microwave heating. For desirable color development, 1-2% lactose is suggested. In general, lactose addition is recommended only in the preparation of pasteurized meat products, as more intense heat treatments can cause undesirable browning reactions to take place.

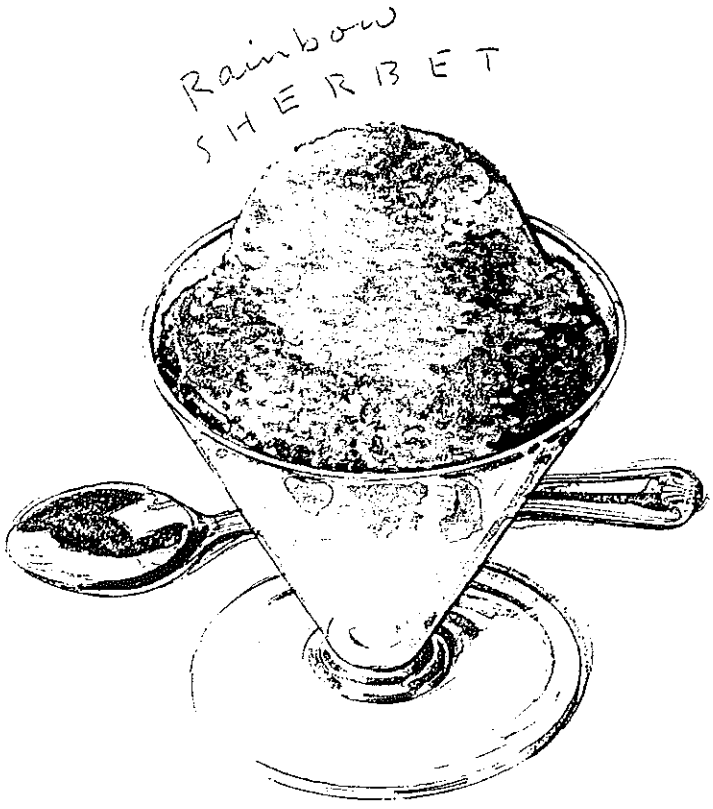
Lactose masks salty and bitter flavors. A usage level of 2-3% causes no undesirable flavor or sweetness changes. The advantage of using lactose at this level is in reducing the taste of added salt and phosphate, and in masking the characteristically strong taste of liver in liver-based spreads or pâtés.

The injection of brine solutions containing lactose also has been reported to have beneficial effects in terms of product and structure formation.

In the preparation of fermented sausages, lactose is very suitable as the carbohydrate necessary for starter cultures. It provides a substrate for the production of lactic acid, which is essential for reducing pH levels. Lactose ensures a controlled rate of pH decrease while limiting the growth of various undesirable microorganisms such as yeast. Starter cultures must be carefully selected and be able to hydrolyze the lactose prior to the fermentation proceeding to lactic acid production. Therefore in most cases, the starter compounds contain lactose and the desired microorganisms. In this case, lactose also acts as a stabilizer for the starter culture. Among the microorganisms, *Lactobacillus* species and *Pediococci* are used during fermentation with lactose as the carbohydrate source. Suggested levels are 1-3% in fermented sausage and 0.5-3.0% in cooked hams.



References



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Bibliography

Aguilar, C.A. and Ziegler, G.R. (1995) Viscosity of molten milk chocolate with lactose from spray-dried whole milk powders. *Journal of Food Science* 60(1): 120.

American Institute of Baking. (1995) *Evaluation of the Effect of Lactose on the Production and Shelf Life of Sponge Cakes and Yellow Layer Cakes,* The American Dairy Products Institute, Chicago.

Blankers, I. (1995) Properties and applications of lactitol. *Food Technology* 49(1): 66.

Brack, G. (1990) Application of Lactose in Flour Confectionery. In *Lactose as a Food Ingredient,* Reimerdes, E.H., Expoconsult Publishers, the Netherlands.

Campbell, L.B. and Pavlasek, S.J. (1987) Dairy products as ingredients in chocolates and confections. *Food Technology* 41(10):84.

Chambers, J.V. and Ferretti, A. (1979) Industrial applications of whey/lactose. *Journal of Dairy Science* 62(1): 112.

Dijksterhuis, J.J. (1990) General Aspects of Milk Sugar. In *Lactose as a Food Ingredient,* Reimerdes, E.H., Expoconsult Publishers, the Netherlands.

Foremost Foods Company. (1981) *Formulation Guide,* Foremost-McKesson Inc.

Godshall, M.A. (1997) How carbohydrates influence food flavor. *Food Technology* 51(1):64.

Groziak, S.M. and Miller, G.D. *Lactose Intolerance: Separating Facts From Myths,* National Dairy Council, Rosemont, IL.

Guy, E.J. (1978) Evaluation of milk caramels containing hydrolyzed lactose. *Journal of Food Science* 43:980.

Holsinger, V.H. (1988) Lactose. In *Fundamentals of Dairy Chemistry*, 3rd ed., Wong, N.P., Van Nostrand Reinhold Co., New York.

Holsinger, V.H. (1997) Physical and Chemical Properties of Lactose. In *Advanced Dairy Chemistry, Vol. 3, Lactose, Water, Salts and Vitamins*, Fox, P.F., Chapman & Hall, London.

Jelen, P. and Chan, C-S. (1981) Firming of canned vegetables by addition of lactose. *Journal of Food Science* 46:1618.

Keller, A.K. *Excellence in Lactose Technology*. Whey Systems Inc., Mantorvile, MN.

Kruger, C. Sweetening chocolate and confectionery with lactitol. In *The World of Ingredients*.

Levitt, M.D. (1994) *Lactose Deficiency, Lactose Malabsorption and Lactose Intolerance*, Presentation ADSA meeting, Minneapolis.

Levitt, M.D., Bond, J.H. and Levitt, D.G. (1981) Gastrointestinal Gas. In *Physiology of the Gastrointestinal Tract*, Johnson, L.R., Raven, New York.

Mahoney, R.R. (1997) Lactose: Enzymatic Modifications. In *Advanced Dairy Chemistry, Vol. 3, Lactose, Water, Salts and Vitamins*, Fox, P.F., Chapman & Hall, London.

Miller, G.D., Jarvis, J.K. and McBean, L.D. *Handbook of Dairy Foods and Nutrition*, CRC Press, Boca Raton, FL.

Morrissey, P.A. (1985) Lactose: chemical and physicochemical properties. In *Developments in Dairy Chemistry*, Vol. 3, Fox, P.F., Elsevier Applied Science Publishers, London.

Mustapha, A., Hertzler, S.R. and Savaiano, D.A. (1997) Lactose: Nutritional Significance. In *Advanced Dairy Chemistry, Vol. 3, Lactose, Water, Salts and Vitamins*, Fox, P.F., Chapman & Hall, London.

National Dairy Council (1997) *Scientific Status Reports.* National Dairy Council, Rosemont, IL.

National Dairy Council. (1995) Calcium Sources: The Case for Foods First. *Dairy Council Digest* 66(1): 1.

National Dairy Council. (1994) Managing Lactose Intolerance. *Dairy Council Digest* 65(2): 10.

National Dairy Council. (1985) Nutritional implications of lactose and lactase. *Dairy Council Digest* 56(5): 25.

National Dairy Council. (1978) *Newer Knowledge of Milk and Other Fluid Dairy Products.* National Dairy Council, Rosemont, IL.

Nickerson, T.A. (1974) *Potential for Hydrolyzed Lactose,* presentation at Whey Products Conference, Chicago.

O'Brien, J. (1997) Reaction Chemistry of Lactose: Non-enzymatic Degradation Pathways and Their Significance in Dairy Products. In *Advanced Dairy Chemistry, Vol. 3, Lactose, Water, Salts and Vitamins,* Fox, P.F., Chapman & Hall, London.

Office of the Federal Register National Archives and Records Administration. (1995) Food and Drugs. In *Code of Federal Regulations Title 21,* Vol. 2: Parts 100-169, U.S. Government Printing Office, Washington, D.C.

Rajah, K.K. and Blenford, D.E. (1988) *Lactose in the Baking Industry,* Association of Lactose Manufacturers, the Netherlands.

Rajah, K.K. and Blenford, D.E. (1988) *The ALM Guide to Lactose Properties & Uses,* Association of Lactose Manufacturers, the Netherlands.

Reimerdes, E.H. (1990) Oligo- and Polysaccharides from Milk Sugar as a Food Ingredient. In *Lactose as a Food Ingredient,* Reimerdes, E.H., Expoconsult Publishers, the Netherlands.

Reimerdes, E.H. (1990) Other Applications of Milk Sugar and Derivatives as Food Ingredients, e.g. Meat Products, Soups, Sauces, Flavors, Fermentations. In *Lactose as a Food Ingredient*, Reimerdes, E.H., Expoconsult Publishers, the Netherlands.

Reimerdes, E.H. (1990) The Outstanding Impacts of Milk Sugar as a Food Ingredient. In *Lactose as a Food Ingredient*, Reimerdes, E.H., Expoconsult Publishers, the Netherlands.

Rosensweig, N.S. (1978) *A Review of Dietary Lactose and Its Varied Utilization by Man*, The Whey Products Institute, Chicago.

Savaiano, D.A. and Levitt, M.D. (1987) Milk intolerances and microbe-containing dairy foods, *Journal of Dairy Science*, 70:397.

Schaafsma, I.G. (1990) Physiological Aspects of Lactose in Human Nutrition. In *Lactose as a Food Ingredient*, Reimerdes, E.H., Expoconsult Publishers, the Netherlands.

Suarez, F.L., Savaiano, D., Arbisi, P. and Levitt, M.D. (1997) Tolerance to the daily ingestion of two cups of milk by individuals claiming lactose intolerance. *American Society for Clinical Nutrition* 65:1502.

Tamura, Y., Mizota, T., Shimaamura, S. and Tomita, M. (1993) Lactulose and its application to the food and pharmaceutical industries. In *Lactose Hydrolysis*, Bulletin 289, International Dairy Federation, Brussels.

Technilab Inc. *Lactulose Solution*, USP. Technilab Inc., Montreal, Canada.

Thelwall, L.A. (1997) Lactose: Chemical Derivatives. In *Advanced Dairy Chemistry, Vol. 3, Lactose, Water, Salts and Vitamins*, Fox, P.F., Chapman & Hall, London.

Timmermans, H.J. (1990) Lactose: A Different Sugar in Confectionery. In *Lactose as a Food Ingredient*, Reimerdes, E.H., Expoconsult Publishers, the Netherlands.

Tong, P.S. (1996) *Lactitol—An Ingredient Derived from Lactose: Composition, Properties and Applicability in Lower Fat Food Formulations,* presentation at IFT Annual Meeting, Anaheim, CA.

van den Bos, M.J. (1987) *Background of Technologies Used for the Production of Lactose,* Bulletin 2127. International Dairy Federation, Brussels.

Zadow, J.G. (1984) Lactose: Properties and Uses. *Journal of Dairy Science* 67 (11): 2658.

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