*5153

THE USE OF MILK POWDERS IN CONFECTIONARY AND BAKERY PRODUCTS

Rory A.M. Delaney
Research and Development Department
Frito-Lay, Inc.
900 N. Loop 12
Irving, TX 75061

Nitin Desai
Research and Development Department
Frito-Lay, Inc.
900 N. Loop 12
Irving, TX 75061

Virginia Holsinger
U.S.D.A.
Eastern Regional Laboratory
600 East Mermaid Lane
Philadelphia, PA 19118

ABSTRACT. Milk powders have been used in the confectionary and bakery industries for many years, largely on an empirical basis, because of their contributions to texture, color, and flavor of the products. Incorporation of milk powders can significantly improve the nutritional value of baked and confectionary goods as well as improve their processability.

This review covers the following aspects of milk powders: production, manufacture, composition, and microstructure of milk powders, functional properties of milk powder components, influence of processing on milk powders, and applications of milk powders in confectionary and bakery products.

1. INTRODUCTION

Milk powders consisting of dry whole milk powder (DWM), nonfat dry milk (NDM), and buttermilk powder (BM) are derived from the dehydration of milk and milk fractions. Milk powders constitute an important part of the food proteins produced on an industrial scale for food applications. Food proteins were first produced due to the necessity to preserve foods, handle wastes, and other economical considerations; they were not produced, per se, for their functional properties. New food products can be fabricated entirely from industrially produced ingredients such as milk or soy proteins, shortenings, and polysaccharides including starch. Milk powder and other food ingredients are frequently added to foods to enhance the structure of the food and the functional properties related to processing and stability of the food product. Milk powders have been traditionally added to confectionary and bakery products as a replacement for fluid milk in the original recipes to improve the organoleptic properties - color, flavor, and texture, as well as the nutritive value of the product. This article reviews the following aspects of milk powders: production, manufacture, composition, and microstructure of milk powders, functional properties of milk powder components, influence of processing on milk powders, and applications of milk powders in confectionary and bakery products.

2. MILK POWDER

2.1 Production and Utilization of Milk Powder

Table I contains data on milk powder production in the USA. If present trends continue, the outlook for 1986 is for a 1% increase in the production of milk powders.

The confectionary and bakery industries have traditionally utilized milk powders as a replacement for fluid milk in the recipes. Typical usage of milk powders in a variety of confectionary and bakery products is shown in Table II. There has been a steady decline in the use of milk powders in the bakery industry in recent years due to replacement of milk powder by other, less expensive sources of food proteins, principally soy proteins and whey protein concentrates. This change has been made possible due to our understanding of the functional role of proteins in foods; thus replacement of expensive or fluctuating sources of proteins, such as milk powders, is possible without sacrificing product quality. The confectionary industry utilizes a large portion of the WMP produced for milk chocolate and candy manufacture. This situation could change if suitable replacements for WMP, for example whey protein concentrate or casein, can be successfully utilized. (Lim, 1980; Dodson, et al. 1984)

2.2 Manufacture of Milk Powders

The manufacture of milk powders involves the concentration and dehydration of milk/skim milk/buttermilk and is most commonly accomplished by spray-drying and, in some cases, by drum drying. Powders obtained by drum drying have very poor reconstitution properties and thus have limited usage. The spray-drying process is described by Masters (1976) and the manufacture of milk powders has been treated by Pallansch (1970), Jensen (1975), and Pisecky (1978), In Figure 1, the process for the manufacture of milk powders is outlined. The physical properties of the powders, e.g. particle size, porosity, bulk density, flowability and wettability, are largely determined by the process and processing conditions (DeVilder et al.

1976; Pisecky, 1978).

Milk crumb, a mixture of dried milk, sugar, and cocoa, is used in the UK for making milk chocolates and coatings. Milk crumb is manufactured by adding sugar to milk at 80°C to obtain an 80% solution. The mix is concentrated to 88% solids and cocoa mass is added to the mix. Sugar is allowed to crystallize (particle size not exceeding 35 microns) in mixers and the mass is moulded in trays, dried to 1-2% moisture. The product is then crushed and milled to obtain milk crumb (Lim, 1980). Milk crumb has good keeping qualities and confectionary products made from milk crumb have better texture and flavor (Edwards, 1984).

2.3 Composition of Milk Powders

Data on the typical composition of milk powders are given in Table III. NDM powder is classified according to the heat treatment given to milk prior to dehydration and is based on the amount of undenatured whey protein in the powder (Table IV). Therefore, when producing NDM powders of certain heat specifications, it is necessary to know the whey protein content in the skim milk and the heat stability of the whey proteins to determine the amount of heat treatment that must be given to milk prior to dehydration to produce NDM powders according to the heat classification (Sørensen et al. 1978). The Harland and Ashworth method, based on turbidity measurements, is used to determine the amount of undenatured whey protein in heat treated milk powders (Kuramoto, et al. 1959). HPLC and DSC methods hold promise as rapid methods for the determination of heat denaturation of proteins in milk products.

2.4 Influence of Processing on Milk Powder Components

There are several process induced changes in the chemical and physiochemical properties of milk powder components. Morr (1984) has summarized these changes for milk proteins (Table V). The manufacture of milk powder involves heating the milk during forewarming, concentration, and spray-drying (Figure 1). Therefore, heat induced changes during manufacture are of significance. Kinsella (1984), Kilara and Sharkasi (1986) have reviewed the functional properties and the influence of heat on milk proteins. Casein micelles are relatively heat stable, whereas the whey proteins, β-lactoglobulin and α-lactalbumin, denature rapidly on heating at 70°C for 30 minutes. Though the casein micelles are heat stable, several large aggregates of the micelles can be observed during electron microscopy of reconstituted NDM. The forewarming stage is the most critical stage during the manufacture of milk powders and largely determines the end use of the spray-dried powder.

The interactions between casein and whey proteins has been extensively studied and it has been theorized that κ-casein, β-lactogobulin and α-lactalbumin interact to form a thermally induced complex. Heat treatment of skim milk normally results in the formation of aggregates and loss of solubility of the protein. In the manufacture of whole milk powder, forewarming to a relatively high temperature is necessary to ensure the inactivation of lipases. Normally, extremely high heat treatment of milk is avoided since protein-sugar interactions leading to browning and protein insolubility can occur. These conditions are generally avoided during the manufacture of milk powders.

The microstructure of milk powders has been examined by scanning electron microscopy (SEM) (Figure 2). Spray-dried NDM particles are spherical in shape and are wrinkled on the surface. The wrinkles on the surface of the particles are caused by the casein in the milk which contracts on the surface of the particles during spray-drying (Buma and Henstra, 1971). These particles also contain large vacuoles which determine the bulk density of the powders.

Graf and Bauer (1976) used electron microscopy to determine the effect of processing and drying of milk on casein micelles. The micrographs in Figure 3 indicate that the processing and drying of milk causes only a slight change in the casein micelle structure. A denser arrangement of micelles can be observed in reconstituted milk when compared to fresh milk. These studies reveal that when milk powder is reconstituted the caseins still exist as micelles.

Lactose in spray-dried milk normally is in the amorphous state. Microstructure studies of milk powders reveal that "instantizing" or agglomeration of the powder leads to the conversion of lactose from a glass form to a more wettable crystalline form. The most common form of lactose observed in NDM powders is the typical tomahawk and prism crystals ranging from 60 to 170 mm in length (Kalab, 1979).

In DWM, fat is present as surface fat on powder particles or in pools and can be easily extracted by solvents. As a result of homogenization, fat is encapsulated by protein and is present as a fat/protein complex. This form of fat is not easily extracted by solvents and may add to the stability of the DWM to lipid oxidation (Buma, 1971; Walstra, and Ooertwijn, 1981).

3. FUNCTIONAL PROPERTIES OF MILK POWDER COMPONENTS IN CONFECTIONARY AND BAKERY PRODUCTS

3.1 Components of Milk

In Figure 4, the breakdown of milk into its components is shown. When milk or milk powder is added to a recipe or a food product, these components impart some characteristic functional, organoleptic and nutritional property to the food.

3.2 Milk Proteins

Casein constitutes approximately 80% of the milk proteins and is composed of α, β, κ, and γ caseins. The milk serum proteins (whey proteins) are composed of α-lactalbumin, β-lactoglobulin, immunoglobulins, proteose peptone, etc.. The proteins of casein readily interact and exist primarily in the form of micelles.

The micelle contains not only casein but also non-protein components such as calcium and phosphorous. Numerous models for the casein micelle have been proposed (Thompson and Farrell, 1974). Among these, the subunit model originally proposed by Morr (1967) and later modified by several researchers is the most widely accepted model. Recently, a subunit model with a "hairy" layer, or a hairy micelle model, has been proposed for the casein micelle (Walstra, et al. 1981; Holt, 1985).

The whey proteins of milk exist as monomers and are also capable of forming larger complexes by means of -S-S- bonds. Casein is an assembly of proteins which does not have higher structures and can be considered as a protein which is denatured in its natural state. Therefore, casein is considered to be relatively heat stable under normal processing conditions. Of the milk proteins, β-lactoglobulin readily undergoes heat denaturation at 55°C or above. Unfolding of the molecule occurs and the -SH groups are exposed. At 70°C or above, irreversible complexes are formed by means of -S-S- bonds. The whey proteins form a complex on heating and the presence of casein accelerates the interaction. The formation of a complex wherein κ-casein, β-lactoglobulin and α-lacalbumin are involved is conceivable.

In recent years the functional properties of food proteins have been extensively studied and many excellent reviews and books have been written on the subject (Pour-El, 1979; Cherry, 1981; Kinsella, 1982).

Kinsella (1970, 1971, and 1984) and Lim (1980) have reviewed the functional properties of milk powders in bakery and confectionary products. There are many important functional properties for proteins in food systems, but in confectionary and bakery products only a few of these properties are of significance since these products are water restricted, low moisture systems (Table VI).

In confectionary products viscosity, gelation, emulsification and fat binding properties are important, whereas in bakery products water binding, emulsification and foaming properties are of significance. The precise role of milk proteins in confectionary and bakery products is not well understood since food systems are highly complex (Figure 5) and functional properties studied in simple model systems may not be applicable to the food system due to interactions. Harper (1984) has suggested a model food system for evaluating protein functionality where the system is designed to study a single or several functional properties of the protein.

Milk protein is essential for the development of texture, flavor, and color of confectionary products such as toffees, caramels, fudges, milk chocolate, marshmallows, and nougats. Sugar, fat, and milk are the basic ingredients of confectionary products. The order of addition and processing conditions determine the textural properties of the products. Milk proteins aid in the emulsification and mixing of the ingredients and influence the viscosity of the matrix. Heating the mix during cooking and subsequent processing results in the unfolding of proteins and formation of fibers by means of -S-S- bonds (Kinsella, 1970). The result is a viscoelastic network which imparts structure and texture to the product. Microstructure studies indicate differences in the structure of confections prepared from DWM and milk crumb, and these differences are related to the association of protein with sugar and cocoa particles (Heathcock, 1985).

The firm chewy texture of several confections are related to the water binding properties of casein. Products such as toffees exhibit "cold-flow" phenomenon when the milk casein is replaced by whey protein (Dodson, et al. 1984). The texture of caramels and toffee is attributed to the emulsifying and water binding properties of milk proteins.

In bakery products, the addition of milk powders increases the amount of water to be added in mixing the dough. The addition of 6% NDM increases the water absorption capacity of dough by approximately 6%. High heat NDM (WPNI $\leq$ 1.6 mg/gram) is used in bakery products, particularly for bread making. Low heat NDM reduces the extensibility of dough and bread with poor loaf volume is obtained. The volume-depressant factor is related to the milk proteins of NDM and the formation of κ-casein and whey protein complex due to heat treatment reduces the effect of the volume-depressant factor (Guy, 1970). These effects may also be related to the -S-S- bond breakage in the dough protein structure whereby weak doughs with reduced carbon dioxide holding properties are produced. Breadmaking by continuous processes generally utilizes NDM at levels below 2% since higher levels produce weak doughs and bread with poor volume. In general, the addition of NDM to bread improves the texture (crumb softness), flavor, and shelf-life of the products (Dubois and Dreese, 1984). The soft texture and increased shelf-life of bread and cookies are attributed to the water binding properties of milk proteins. In cakes, NDM aids in better foam structure and texture.

3.3 Milk Lipids

The lipid content of milk powders is shown in Table III. Milk fat is typically composed of triglycerides (97%), mono- and diglycerides (1-2%), and phospholipids (1-2%). WDM contains 27-28% fat and its role in confectionary products can be characterized as: (1) impart structure and texture to the product, (2) the surface active ingredients present in fat (mono- and diglycerides and phospholipids) affect the viscosity and emulsifying properties of the mix during processing, (3) impart flavor to the product. Milk fat is compatible with cocoa butter and DWM can be added to confectionary products without altering the properties of fat. In confectionary making the oxidation of lipids by lipases and heat is encouraged to develop important flavor components. Oxidation of fat, leading to the development of the typical undesirable rancid flavor in milk powders, determines the shelf-life of the powders. The aroma compounds of milk and dairy products have been reviewed by Badings and Neeter (1980). The role of flour lipids in baking has been reviewed by Chung (1986); the significance of the role of lipids added as a milk powder constituent has not been elucidated. The surface active properties of lipid constituents in milk powder may be of some significance during baking. BM contains large amounts of surface active membrane material which would affect the viscosity and emulsifying properties of the dough or mix during processing. BM is added to bakery products to improve the flavor and shelf-life of baked products.

3.4 Lactose

Milk powders are high in lactose (35-50%) which impart important organoleptic and textural characteristics to the product. Lactose is present in milk powders in both amorphous and crystalline states and these determine the wetting properties of milk powders. Lactose plays a predominant role in imparting a characteristic color and flavor to confectionary and bakery products. Browning reactions occurring between free amino acids and lactose are well known in food products as non-enzymatic browning or Maillard reactions which produce the color and flavor of these products (Hodge and Osman, 1976). Another mechanism whereby milk sugars impart color and flavor to products is by dehydration reactions leading to yellow-brown pigments and flavor components (Kinsella, 1970). In confectionary products, lactose imparts graininess/grittiness to the products and is a desirable textural characteristic in hard candies. Addition of milk powders to bakery products improves the crust color due to browning reactions of lactose.

3.5 Minerals and Salts

The mineral and salt content of milk powders is shown in Table VII. Dairy powders are an excellent source of calcium and phosphorus and significantly improve the nutritional value of confectionary and bakery products. The effect of calcium and other divalent cations is well known in the gelling of several polysaccharides like alginates and carrageenan. Such an effect has not been demonstrated for the polysaccharides present in wheat. Studies indicate that the mineral content of NDM added to dough prolongs the fermentation time of the doughs due to the buffering action of the milk powder and decreases the amylase activity (Pyler, 1973).

4. CONCLUSION

The constituents of milk powder components play important functional roles in confectionary and bakery products. The selection and continued use of milk powder as an ingredient in these products will be largely determined by price, process functionality, and contribution to nutritive value.

5. ACKNOWLEDGEMENTS

The assistance of Ms. Elizabeth Ott in preparing this manuscript is gratefully acknowledged.

FIGURE 1
PROCESS FOR THE MANUFACTURE OF MILK POWDERS

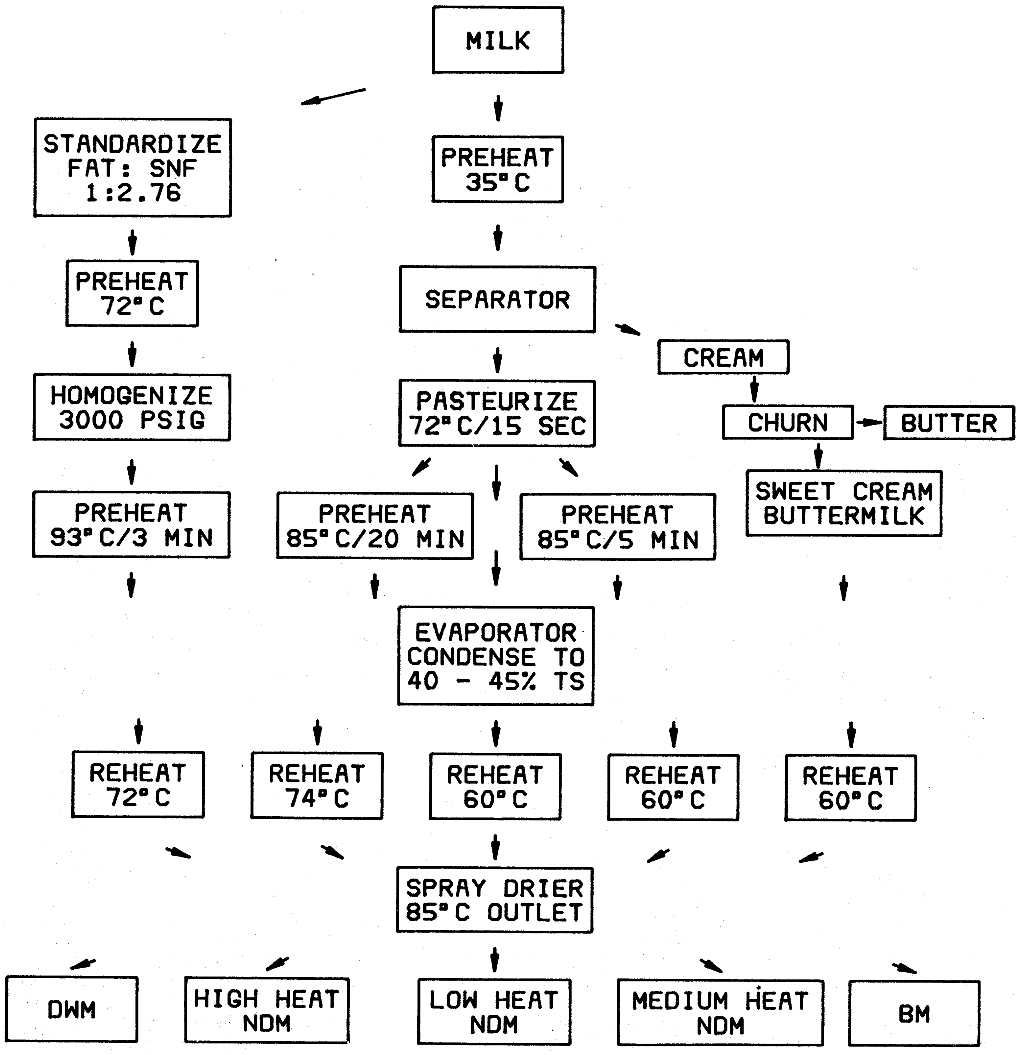


FIGURE 2
SCANNING ELECTRON MICROGRAPHS OF SPRAY-DRIED MILK POWDERS

Note the smooth and wrinkled surfaces of the particles. In the lower micrographs, the interior of the particles is visiable and contain trapped milk globules. (Reprinted with permission of SEM Inc., USA.)

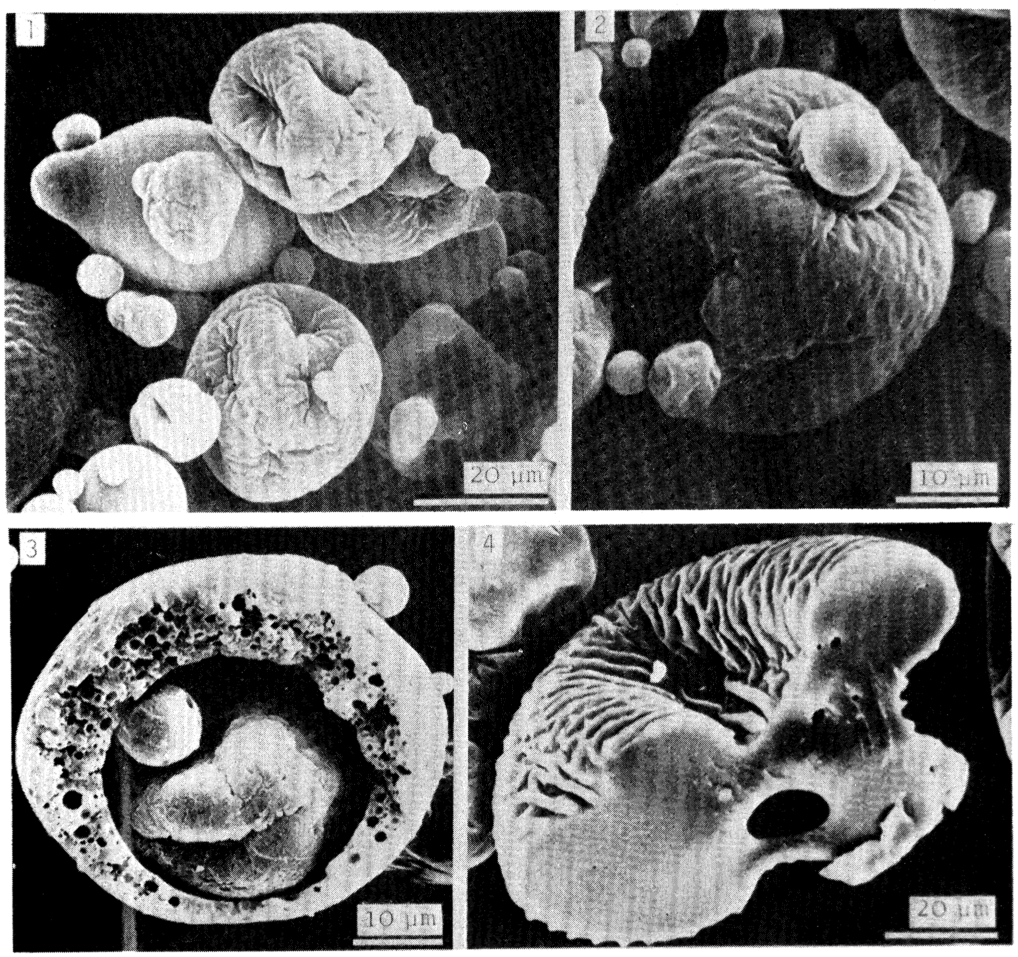


FIGURE 3

(a) Casein micelles in fresh cream. The subunits are relatively loosely packed

(b) Casein micelles of a reconstituted unhomogenized milk powder. Note the denser packing of the subunits compared to 3(a).

(Reprinted with permission of Marcel Dekker, Inc., New York.)

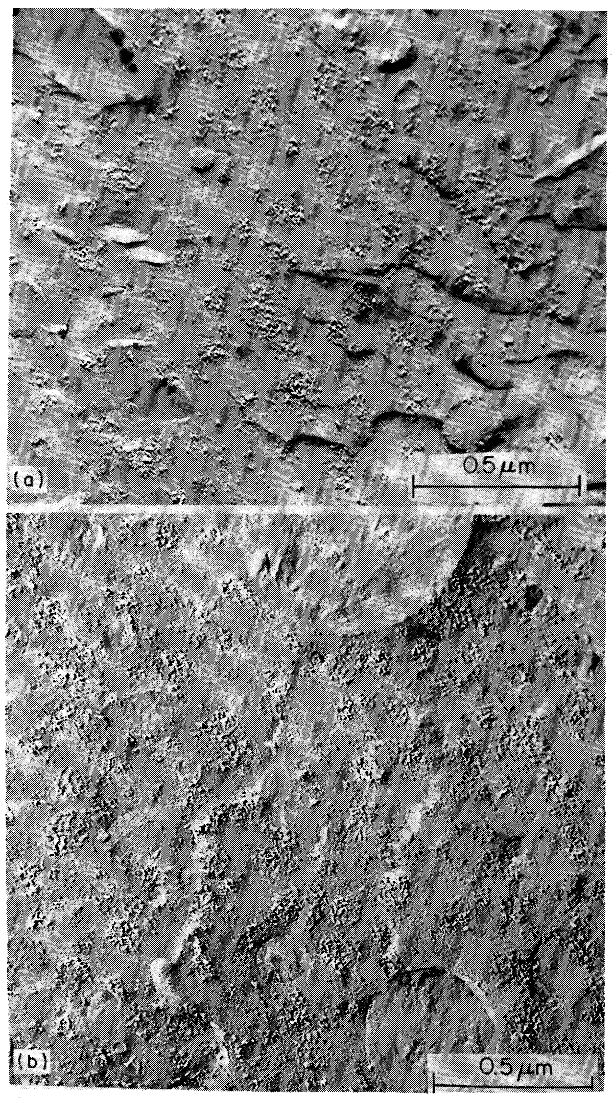
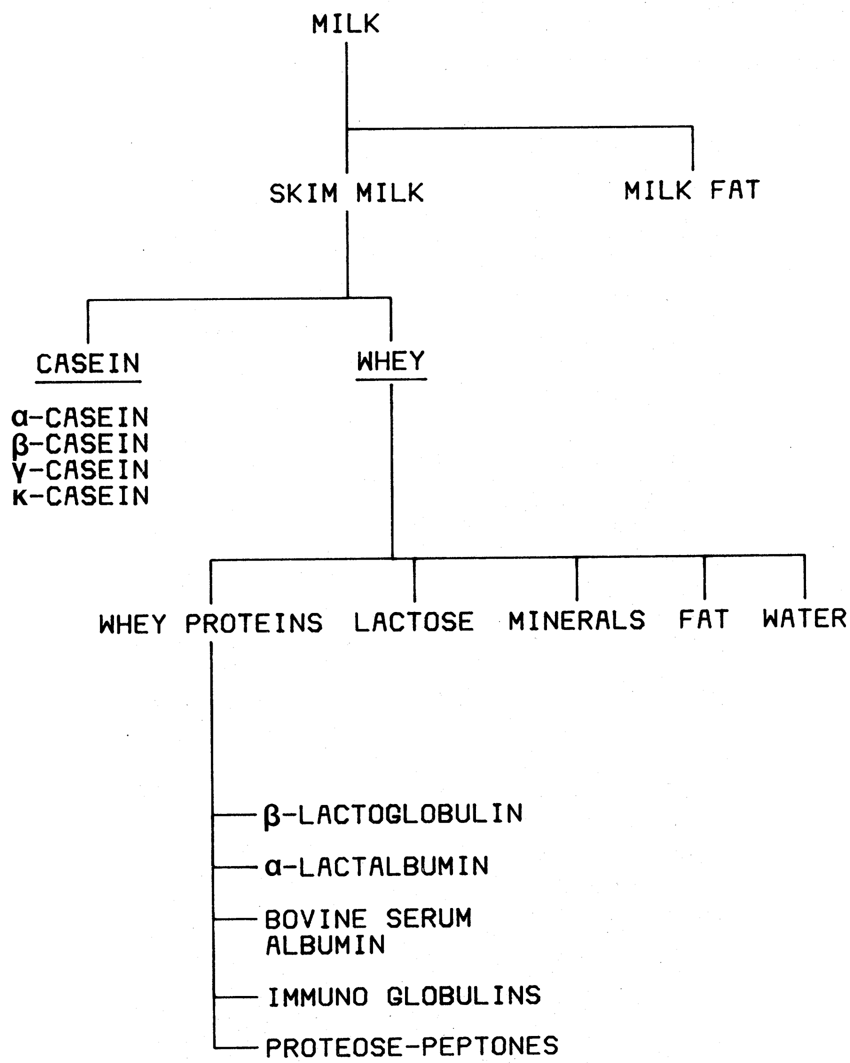


FIGURE 4
SCHEMATIC BREAKDOWN OF MILK INTO ITS COMPONENTS



Milk Powder Type	Year 1980	1981	1982	1983	1984	1985
Nonfat dry milk (NDM)	1,160.7	1,314.7	1,400.2	1,499.9	1,160.7	1,390.0
Dry whole milk (DWM)	82.7	92.7	102.2	111.2	119.6	118.9
Buttermilk (BM)	---	---	---	---	---	36.9

[a]Values in millions of pounds. Data from USDA Reports and American Dry Milk Institute

FIGURE 5

Figure showing the complex interactions of food ingredients in a simple food system. (Adapted from Harper, 1984.)

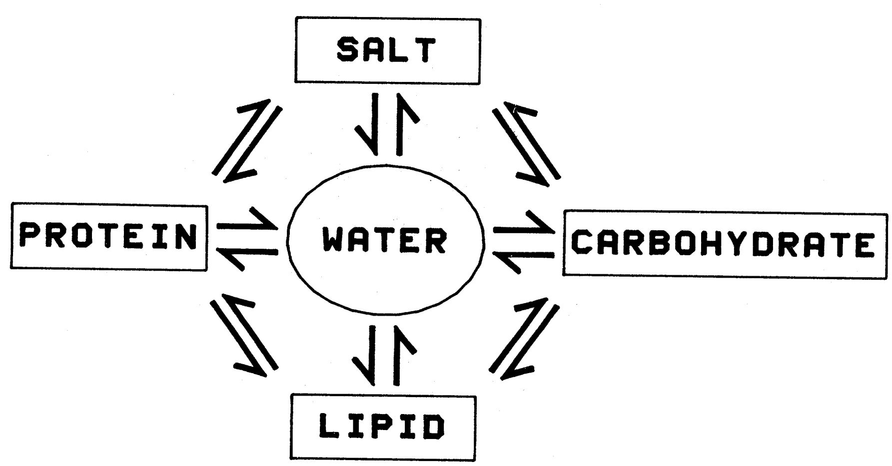


TABLE II
BAKERY AND CONFECTIONERY PRODUCTS CONTAINING MILK POWDERS

Food Commodity	Approximate Amount Added (%)		
	DWM	NDM	BM
Bread	+	1-6	+
Rolls	+	1-6	+
Cakes	1-10	5-10	0-2
Cookies	0-5	2-10	0-2
Crackers	-	2-5	-
Doughnuts	0-3	2-8	-
Danish pastry	0-2	3-15	+
Pretzels	-	3-10	-
Biscuits	0-5	5-8	2
Pies	0-10	4-8	+
Cake mixes (dry)	0-10	10-20	+
Pancake mixes	0-5	7-12	+
Waffles	-	10-15	-
Pizza dough	-	-	-
Macaroni	-	12-25	-
Batters (meats)	1-2	0-5	-
Icings & frostings	0-20	5-30	+
Chocolate	0-30	5-20	+
Fudge, fondants	0-15	3-20	+

Adapted from Kinsella (1971).

TABLE III
COMPOSITION OF VARIOUS TYPES OF MILK POWDERS, 100 GRAMS[a]

Component (%)	DWM	NDM Instant	NDM Regular	BM
Water	2.0	3.0	4.0	2.8
Protein	25.4	35.9	35.8	34.3
Fat	27.5	0.8	0.7	5.3
Carbohydrate	38.2	52.3	51.6	50.0
Ash	5.9	8.0	7.9	7.6

[a]From USDA Agriculture Handbook No. 8 (Watt and Merrill, 1975).

TABLE IV
CLASSIFICATION OF NDM BASED ON UNDENATURED WHEY PROTEIN INDEX (WPNI)[a]

Classification	WPNI/Gram Powder
High heat powder	$\leq$ 1.5 mg.
Medium heat powder	1.51 - 5.99 mg.
Low heat powder	$\geq$ 6.0 mg.

[a]American Dry Milk Institute, Bulletin No. 916.

TABLE V
PROCESSING INDUCED CHANGES IN CHEMICAL AND PHYSIOCHEMICAL PROPERTIES OF MILK PROTEINS[a]

Heating	Interaction of whey proteins with caseins Denaturation of whey proteins Aggregation of whey proteins Maillard browning reaction between proteins and lactose Activation of whey protein sulfhydryl groups
Acid treatment	Solubilize colloidal calcium phosphate from casein micelles Lower heat stability of milk proteins Precipitate casein and denatured whey proteins
Addition of calcium ions	Alter casein micelle structure and composition Lower heat stability Promote milk protein aggregation when heated
Rennet treatment	Hydrolyze κ-casein to release glycomacropeptide Lower zeta potential on casein micelle Coagulate modified casein micelles

[a]Morr (1984). Reprinted from Journal of Food Technology, with permission

TABLE VI
FUNCTIONAL PROPERTIES OF PROTEINS IN CONFECTIONARY AND BAKERY PRODUCTS

Major Functional Properties	Minor Functional Properties
Water binding	Foam stabilization
Viscosity (rheological influence)	Water holding capacity
Emulsification	Fat binding
Gelation	Flavor

TABLE VII
APPROXIMATE LEVELS OF MINERAL CONSTITUENTS IN DRY MILKS[a]

Salt Constituent	DWM	NDM	BM
	(mg per 100g)		
Major Minerals			
Calcium	909.0	1293.0	1248.0
Sodium	405.0	526.0	507.0
Potassium	1130.0	1725.0	1606.0
Phosphorus	709.0	1005.0	970.0
Chlorine	1200.0	820.0	1100.0
Magnesium	100.0	70.0	95.0
Sulfur	85.0	63.0	80.0
Trace Elements			
Zinc	1.1	1.5	1.4
Iron	0.6	0.5	0.6
Copper	0.06	0.07	0.07
Manganese	0.04	0.06	0.06
Cobalt	0.002	0.002	0.002
Molybdenum	0.05	0.07	0.07
Iodine	0.34	0.46	0.44
Bromine	2.6	3.5	3.3
Flourine	0.11	0.15	0.13
Organic Salts			
Citrates (as citric acid)	1500	2000	1900
Lactates (as lactic acid)	40	50	50

[a]Adapted from <u>USDA Handbook No. 8</u> (Watt and Merrill, 1978) and Pedraja (1965).

6. REFERENCES

Badings, H. T., and Neeter, R. 1980. 'Recent Advances in the Study of Aroma Compounds of Milk and Dairy Products.' Netherlands Milk Dairy Journal **34** (1), 9.

Buma, T. J. 1971. 'Free-Fat in Spray-Dried Whole Milk. 8. The Relation Between Free-Fat Content and Particle Porosity of Spray-Dried Whole Milk.' Netherlands Milk Dairy Journal **25**, 123.

Buma, T. J., and Henstra, S. 1971. 'Particle Structure of Spray-Dried Caseinate and Spray-Dried Lactose as Observed by Scanning Electron Microscopy.' Netherlands Milk Dairy Journal **25** (9), 278.

Cherry, J. P. 1981. Protein Functionality in Foods. Washington, D.C.: American Chemical Society

Chung, O. K. 1986. 'Lipid Protein Interactions in Wheat Flour, Dough, Gluten, and Protein Fractions.' Cereal Foods World **31** (3), 242.

DeVilder, J., Martens, R. as, Naudts, M. 1979. 'The Influence of the Day Matter Content, the Homogenization and the Heating of Contrate on Physical Characteristics of Whole Milk Powder.' Milchwissenschaft **34** (2), 78.

Dodson, A. G., Beacham, J., Wright, S. J. C., and Lewis D. F. 1984. 'Role of Milk proteins in Toffee Manufacture. Part 1. Milk Powders, Condensed Milk and Wheys.' Leatherhead Food R.A. Research Report No. 491.

Dubois, D. K., and Dreese, P. 1984. In Dairy Products for the Cereal Industry. Edited by J. L. Vetter. St. Paul, MN: AACC.

Edwards, W. P. 1984. 'Uses for Dairy Ingredients in Confectionary.' Journal of the Society of Dairy Technologists **37** (4), 122.

Graf, E., and Bauer, H. 1976. In Food Emulsions. Edited by S. Friberg. Marcel Dekker.

Guy, E. J. 1970. In Byproducts From Milk. Edited by B. H. Webb and E. O. Whittier. AVI.

Harper, W. J. 1984. 'Model Food System Approaches for Evaluating Whey Protein Functionality.' Journal of Dairy Science **67**, 2745.

Heathcock, J. F. 1985. 'Characterization of Milk Proteins in Confectionary Products.' Food Microstructure **4**, 17.

Hodge, J. E., and Osman, E. M. 1976. In Food Chemistry. Edited by E. O. Fennema. Marcel Dekker.

Holt, C. 1985. 'The Size Distribution of Bovine Casein Micelles: A Review.' Food Microstructure **4**, 1.

Jensen, J. D. 1975. 'Some Recent Advances in Agglomerating, Instantizing, and Spray Drying.' Food Technology **29** (6), 60.

Kalab, M. 1979. 'Scanning Electron Microscopy of Dairy Products: An Overview.' Scanning Electron Microscopy III, 261.

Kilara, A., and Sharkasi, T. Y. 1986. 'Effects of Temperature on Food Proteins and Its Implications on Functional Properties.' CRC Critical Reviews Food Science Nutrition **23** (4), 323.

Kinsella, J. E. 1970. 'Functional Chemistry of Milk Products in Candy and Chocolate Manufacture.' Manufacture of Confections **50** (10), 45.

Kinsella, J. E. 1971. 'The Chemistry of Dairy Powders with Reference to Baking.' Advanced Food Research **19**, 147.

Kinsella, J. E. 1982. In Food Proteins. Edited by P. F. Fox and J. J. Cowden. Applied Science Publications.

Kinsella, J. E. 1984. 'Milk Proteins: Physiochemical and Functional Properties.' CRC Critical Reviews Food Science Nutrition **21** (3), 197.

Kuramoto, S., Jenness, R., Coulter, S. T., and Choi, R. P. 1959. 'Standardization of Harland-Ashworth Test for Whey Protein Nitrogen.' Journal of Dairy Science **42** (1), 28.

Lim, D. M. 1980. 'Functional Properties of Food Proteins with Particular Reference to Confectionary Products.' Leatherhead Food RA Research Report No. 120.

Masters, K. 1979. Spray Drying Handbook. Halstead Press.

Morr, C. V. 1967. 'Effect of Oxalate and Urea Upon Ultracentrifugation Properties of Raw and Heated Skim Milk Casein Micelles.' Journal of Dairy Science **50** (11), 1744.

Morr, C.V. 1984. "Production and Use of Milk Proteins in Food.' Food Technology **38** (7), 39.

Pallansch, M. J. 1970. In By-Products From Milk. Edited by B. H. Webb and E. O. Whittier, AVI.

Pisecky, J. 1978. 'Bulk Density of Milk Powders.' Dairy Industry International **43** (2), 4.

Pisecky, J. 1978. 'Instant Whole Milk Powder.' Dairy Industry

International 43 (8), 5.

Pour-El, A. 1979. Functionality and Protein Structure. Washington, D.C.: American Chemical Society.

Pyler, E. J. 1973. Baking Science and Technology, Vol. 1. Chicago: Siebel Publishing Company.

Sørensen, H. I., Krag, J., Pisecky, J., and Westergaard, V. 1978. Analytical Methods for Dry Milk Products. Denmark: A/S Niro Atomizer.

Thompson, M.P. and Farrell, H. M. 1973. 'The Casein Micelle - The Forces Contributing to Its Integrity.' Netherlands Milk Dairy Journal **27** (2/3), 220.

Walstra, P. and Oortwijn, H. 1982. 'The Membranes of Recombined Fat Globules, III. Mode of Formation.' Netherlands Milk Dairy Journal **36**, (2), 103.

Walstra, P. W., Bloomfield, V. A., Wei, G. J., and Jenness, R. 1981. 'Effect of Chymosin Action on the Hydrodynamic Diameter of Casein Micelles.' Biochemistry Biophysics Acta **669**, 258.