Dairy Powders and Concentrated Products

Edited by

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Dairy Powders and Concentrated Products

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Contents

Preface to the Technical Series

For more than 60 years, the Society of Dairy Technology (SDT) has sought to provide education and training in the dairy field, disseminating knowledge and fostering personal development through symposia, conferences, residential courses, publications and its journal, the *International Journal of Dairy Technology* (previously known as the *Journal of the Society of Dairy Technology*).

In recent years, there have been significant advances in our understanding of milk systems, probably the most complex natural food available to man. Improvements in process technology have been accompanied by massive changes in the scale of many milk processing operations, and the manufacture of a wide range of dairy and other related products.

The Society has now embarked on a project with Blackwell Publishing to produce a Technical Series of dairy-related books to provide an invaluable source of information for practising dairy scientists and technologists, covering the range from small enterprises to modern large-scale operation. This latest volume in the series, *Dairy Powders and Concentrated Products,* under the editorship of Dr A.Y. Tamime, provides a timely and comprehensive update on the principles and practices involved in producing these concentrated milk and milk fractions. Though the final products are often shelf stable, the milder methods now used to aid the retention of the nutritional and functional properties have led to a further increase in hygiene standards within the industry. While some products, for instance infant formulae, provide a complete food, a new sector has developed within the dairy industry to provide specialised ingredients to the food industry. This book provides a valuable review of the progress being made in the provision of these products.

Andrew Wilbey
Chairman of the Publications Committee, SDT
September 2008

Preface

Given the recent developments in dairy technology, it has become apparent that the revision of the Society of Dairy Technology publication (Milk and Whey Powders – published in 1980) is overdue. Although there have been some technological developments in the manufacture of these products, including concentrated and sweetened condensed milk, over the past couple of decades, the total world production figures in 2005 ($\times$1000 tonnes; as reported by the International Dairy Federation of the main dairy-producing countries) of condensed products and dairy powders are 1777.6 and 3025.8, respectively. The economic importance of these products to dairy-producing countries is very significant, and there is a large demand for them in countries where milk production is low or non-existent. In these markets, dairy products are made locally to meet the demand of consumers from recombined powders, anhydrous milk fat and concentrated dairy ingredients (evaporated and sweetened condensed milk).

Dairy Powders and Concentrated Products is the latest book in the Technical Series of The Society of Dairy Technology. Numerous scientific data are available in journals and books that have been published since the early 1990s, and the primary aim of this text is to detail in one publication the manufacturing methods, scientific aspects and properties of milk powders (full-fat, skimmed and high-protein powders made from milk retentates), whey powders including whey powder concentrates, lactose, caseinates, sweetened condensed milk, evaporated milk and infant baby feed. The book also covers the international standards relating to these products for trading purposes, as well as the hazards such as explosion and fire that may occur during the manufacture of dairy powders.

The authors, who are all specialists in these products, have been chosen from around the world. The book will be of interest to dairy scientists, students, researchers and dairy operatives around the world and will become an important volume in the Technical Series of Society of Dairy Technology.

A.Y. Tamime
Technical Series Editor
September 2008

This book is dedicated to the memory of Dr Richard Robinson, who generously devoted much time and effort to checking the text of the volumes in the SDT technical series prior to publication.

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1 Chemistry of Milk – Role of Constituents in Evaporation and Drying

H.C. Deeth and J. Hartanto

1.1 Introduction

This chapter discusses the relevance of major milk components to concentrated and dried products, the chemical composition of the various products and some of the quality issues of the products associated with the various components. Knowledge of the chemical composition of these products is essential for understanding their manufacture, applications, nutritional attributes, essential chemical differences and functional properties, as well as the changes that occur during their manufacture and storage. Several comprehensive reviews of the chemical composition of milk are available in dairy chemistry texts and other publications (e.g. Walstra & Jenness, 1984; Wong *et al*., 1988; Fox & McSweeney, 1998; Varnam & Sutherland, 2001; Anonymous, 2003; Walstra *et al*., 2006).

Many factors affect the composition of milk. These include the species and breed of animal from which the milk is derived, the stage of lactation, the season and the nutritional status and health of the animal. In addition, changes to the milk occur after it is harvested and before it is processed, which may affect its processibility. Therefore, it is impossible to provide accurate compositional data. In Table 1.1, 'textbook values' of the major constituents, water, fat, protein, carbohydrate (lactose) and minerals or ash are given for whole milk and skimmed milk, that is, milk from which fat has been removed. Table 1.1 also gives compositional data for a range of concentrated and dried milk products selected from a range of sources. As for the composition of milk, several factors affect the composition of these products also. These include the factors that affect the unprocessed milk and also many processing and storage variables. Therefore, the data in Table 1.1 should be used as a guide only to the composition of particular products. Figure 1.1 shows a graphical comparison of the proximate compositions of the major dried products. For the sake of this illustration, the water content of the powders is assumed to be zero. In practice, however, the water content is approximately 3–5 g 100 g^{-1}.

Table 1.1 and Figure 1.1 illustrate a wide range of compositions of the concentrated and dried milk products. In the following sections, these aspects are discussed in relation to the composition and quality aspects of the concentrated and dried products.

1.2 Chemical components of liquid, concentrated and dried milk products

1.2.1 *Protein*

Both the protein content and protein composition are important in milk concentrates and powders, with some products being characterised by their protein content. For example,

Table 1.1 Proximate composition (g 100 g^{-1}) of liquid, concentrated and dried milk products.

Product	Water	Fat	Protein	Carbohydrate	Ash/minerals
Liquid milks					
Whole milk	87	3.7	3.3	4.8	0.7
Skimmed milk	90	<0.1	3.4	4.9	0.75
Concentrated milks					
Evaporated whole milk					
American standard	72.7–74.7	7.5–8.0	6.5–7.1	9–10	1.3–1.6
British standard	67–69	9–10	8–9	11.0–12.5	1.9–2.1
Evaporated skimmed milk	79.5	0.3	7.6	11	1.6
Sweetened condensed milk	27	9	8	55	1.8
Sweetened condensed skimmed milk	28	0.3	10	59	2.3
Milk powders					
Whole milk powder	2–4	25–28	25–27	37–38	6–7
Skimmed milk powder	3–5	0.7–1.3	35–37	49–52	7.5–8.0
Buttermilk powder	2.8–3.8	3–6	33–36	47–49	7–8
Cream powder	2.6–3.0	55–70	12–15	13–24	2.0–3.5
Milk and whey protein powders					
MPC 42	3.5	1.0	42	46.0	7.5
MPC 70	4.2	1.4	70	16.2	8.2
MPC 75	5.0	1.5	75	10.9	7.6
MPC 80	3.9	1.8	80	4.1	7.4
MPC 85	4.9	1.6	85	1.0	7.1
High milk protein powder	5.3	2.3	88	0.7	7
Caseinate (Ca, K, Na)	3–5	0.9–1.5	89–95	0.2	3.3–5
Casein (acid)	9.5	0.8	97	0.1	1.8
Casein (rennet)	9.5	0.8	90.5	0.1	8.5
Low-protein WPC	4.6	2–4	34–36	44–53	7–8
Medium-protein WPC	4.3	5	53	35	7
High-protein WPC	3–4	4–6	59–65	21–22	3.5–4
Very high-protein WPC	4–5	0.3–7.0	72–81	2–13	2.5–6.5
Whey protein isolate	2.5–6	0.1–0.7	89–93	0.1–0.8	1.4–3.8
Fractionated whey proteins					
α-fraction	4.5	1.0	81.5	7	3.4
β-fraction	4.5	0.4	87	0.5	3.0

Table 1.1 Continued.

Product	Water	Fat	Protein	Carbohydrate	Ash/minerals
Milk/whey protein hydrolysate	4	5	81.5	3	4.5
Whey powders					
Whey powder (acid)	≤3.5	0.8	9–12	65–69	11–12
Whey powder (sweet)	3–6	0.8–1.5	12–13	70–73	7.5–8.5
Whey powder (demineralised)	≤3	≤1.5	≥11	78–82	≤4
Whey powder (demineralised)	≤3	≤1.5	≥11	80–84	≤1.5
Whey powder (deproteinised)	3	0.2–1	2.5	80–85.5	8.5–10
Whey powder (lactose-reduced)	2–3	1–4	18–25	40–60	11–27
Miscellaneous products					
Lactose (food grade)	0.5	0.1	0.1	99	0.1–0.3
Infant formula	2–3	26–39	10–18	40–60	8

MPC = milk protein concentrate; WPC = whey protein concentrate.

Data compiled from Hargrove & Alford (1974), Posati & Orr (1976), Walstra & Jenness (1984), Morr (1984), Bassette & Acosta (1988), Jensen (1990), Morr & Foegeding (1990), Morr & Ha (1993), Caric (1993), Haylock (1995), Huffman (1996), Early (1998), Australian Dairy Corporation (1999), Pintado *et al*. (1999), Holt *et al*. (1999), O'Malley *et al*. (2000), Mistry (2002), Fox (2002, 2003), Mleko *et al*. (2003), Thomas *et al*. (2004), Kim *et al*. (2005), FSANZ (2006), Walstra *et al*. (2006), Millqvist-Fureby & Smith (2007) and Sinha *et al*. (2007).

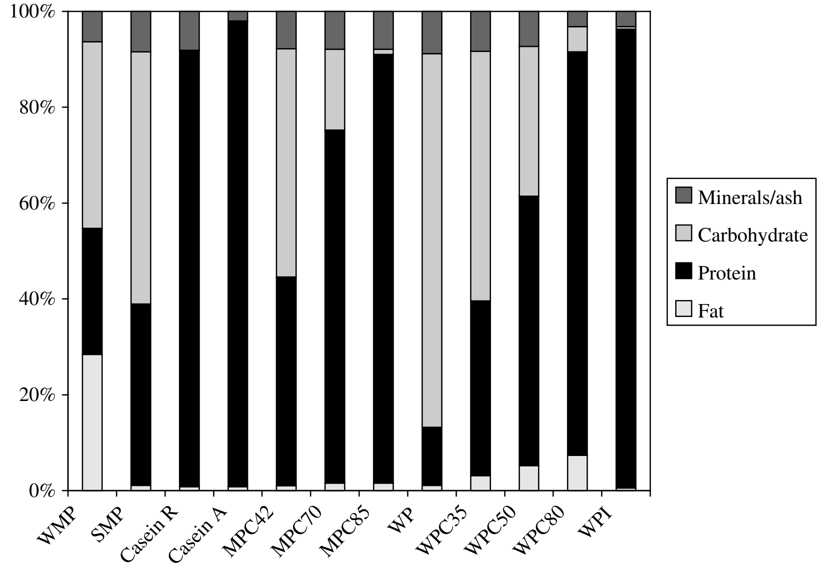

Fig. 1.1 Proximate composition of major milk-derived powders.
WMP = whole milk powder; SMP = skimmed milk powder; MPC = milk protein concentrate; WP = whey powder; WPC = whey protein concentrate; WPI = whey protein isolate; numbers following abbreviations denote approximate protein percentages.

milk protein concentrates (MPC) and whey protein concentrates (WPC) are marketed on the basis of their protein content, for example, WPC80 contains 80 g 100 g^{-1} protein powder. In most cases, the nominal protein content is a crude protein figure, not a true protein figure. The non-protein nitrogen components, such as urea, represent the difference between these two values.

The proteins in milk consist of two broad types, the caseins that are insoluble at pH 4.6 and the whey proteins that are soluble at this pH. About 80 g 100 g^{-1} of the protein is casein and the remainder is whey proteins. Hence, the casein: whey protein ratio in milk is ~4:1. A third minor class is the membrane proteins that form part of both the milk fat globule membrane and the skimmed milk membrane material. The membrane proteins have only a minor role in the properties of most concentrates and powders.

Table 1.1 and Figure 1.1 also show the difference in the protein contents of different powders. Four types of powder stand out as having a high protein content – casein (both acid and rennet), high-protein MPC such as MPC85, high protein WPC such as WPC80 and whey protein isolate. However, the type of protein differs considerably, with caseins being almost entirely casein, MPC containing both casein and whey protein in the same proportion as the original milk and the whey protein products containing mostly whey protein with only a minor amount of casein. Fractionated whey proteins, such as the alpha and beta fractions contain predominantly the whey proteins α-lactalbumin and β-lactoglobulin, respectively.

In Table 1.1 and Figure 1.1, the compositions of two different caseins are shown. This is a good example of a product with the same name produced by different methods having different compositions. Rennet casein produced by coagulation of casein by the action of chymosin (in rennet) is depleted in the glycomacropeptide or casein-derived peptide of κ-casein that remains in the whey, while acid casein, produced by the acid precipitation of casein, contains the complete caseins. This also means that the corresponding rennet and acid wheys differ also with rennet whey containing a substantial amount of the glycomacropeptide (~15 g 100 g^{-1} of the protein), which is not present in acid whey.

In milk, most of the casein exists in the form of casein micelles that contain the four major caseins, α_{s1}-, α_{s2}-, β- and κ-caseins in the ratio of approximately 40:10:35:12. In addition, about 6 g 100 g^{-1} of the solid material in the micelle is colloidal calcium phosphate that acts as 'glue' to help maintain the integrity of the micelle. If the calcium phosphate is removed from the micelle, for example by acidification, the micelles are disrupted and the casein coagulates into curd. Therefore, the form in which the caseins exist in milk products is determined by the processing procedures used. For example, caseins that are produced by acid precipitation are largely in non-micellar form, while the casein in skimmed milk powder (SMP) or MPC is largely 'micellar' (Mulvihill & Ennis, 2003). However, it should be noted that though micelles in milk contain 4–5 g water g^{-1}, the dried micelles in powders contain little water and, hence, are quite different from native micelles.

The micelles in milk range in size from 30 to 300 nm diameter (Varnam & Sutherland, 2001). However, after heat treatment they increase in size. Martin *et al.* (2007) found that the size of the micelles increased on average by ~3, 6 and 39 nm after low-heat (79°C for <5 s), medium-heat (90°C for 30 s) and high-heat (120°C for 4 min) treatment of skimmed milk. This increase is due to the attachment of denatured whey proteins onto the micelles (Oldfield *et al.*, 2005). Removal of water by evaporation resulted in much larger