11

Functional dairy products

M. Saxelin, R. Korpela and A. Mäyrä-Mäkinen, Valio Ltd, Finland

11.1 Introduction

Dairy products form the major part of functional foods. To understand their success it is important to know that milk is a natural and highly nutritive part of a balanced daily diet. Designing and developing functionality in dairy-based products simply means modifying and/or enriching the healthy nature of the original base. This chapter is a brief introduction to the composition of milk and the nature of fermented milk products. It also gives a few definitions and introduces some of the functional dairy products on the market. The purpose of this chapter is not to evaluate the quality and depth of the science behind each product: some of these products are tested in their final state, while the functionality of others is based on accepted knowledge of a particular compound. At the same time, this chapter offers some 'good guesses' as to the potential development of functional dairy foods in the future.

11.2 Composition of milk

The milks of various mammalian species differ in the amount and type of their components. This review focuses on cows' milk and those products of which cows' milk forms a prominent ingredient. Cows' milk is mainly composed of water, with approximately 4.8% lactose, 3.2% protein, 3.7% fat, 0.19% non-protein nitrogen and 0.7% ash. The principal families of proteins in milk are caseins, whey proteins and immunoglobulins. About 80% of proteins are caseins (Banks and Dalgleish, 1990).

Caseins (α_{s1}-, α_{s2}-, β- and κ-) and whey proteins differ in their physiological and biological properties. Caseins form complexes called micelles with calcium. Globular α-lactalbumin and β-lactoglobulin are the main whey proteins. They constitute 70–80% of the total whey proteins, the remainder being immunoglobulins, glycomacropeptide, serum albumin, lactoferrin and numerous enzymes. Some of the biological properties of milk proteins are shown in Table 11.1. Milk proteins are a rich source of precursors of biologically active peptides. Bioactive peptides are formed by the enzymatic hydrolysis of proteins or by the proteolytic activity of lactic acid bacteria in microbial fermentations. Many of the peptides survive through the intestinal tract. Bioactive peptides are also formed *in vivo* by the enzymatic hydrolysis of the digestive enzymes. Table 11.2 shows some bioactive peptides derived from milk proteins, and also their functions.

Milk fat is a complex of lipids, and exists in microscopic globules in an oil-in-water emulsion in milk. The majority of milk lipids are triglycerides or the esters of fatty acids combined with glycerol (97–98%), and the minority are phospholipids (0.2–1%), free sterols (0.2–0.4%) and traces of free fatty acids. About 62% of milk fat is saturated, 30% monounsaturated (oleic acid), 4% polyunsaturated and 4% of minor types of fatty acids (Miller *et al.*, 2000).

Lactose is the principal carbohydrate in milk. It is a disaccharide formed from galactose and glucose. Lactose forms about 54% of the total non-fat milk solids. It also provides 30% of the energy of milk. In addition to high-value protein, milk also provides vital minerals and vitamins. It is an important source of minerals, in particular of calcium, phosphorus, magnesium, potassium and trace elements such

Table 11.1 Biological activities of major cows' milk proteins (Korhonen *et al.*, 1998)

Protein	Suggested functions	Concentration (g/l)
Caseins (α, β and κ)	Iron carrier (Ca, Fe, Zn, Cu) Precursors of bioactive peptides	28
α-Lactalbumin	Lactose synthesis in mammary gland, Ca carrier, immunomodulation, anticarcinogenic	1.2
β-Lactoglobulin	Retinol carrier, fatty acids binding, possible antioxidant	1.3
Immunoglobulins A, M and G	Immune protection	0.7
Glycomacropeptide	Antiviral, antibacterial, bifidogenic Releases protein to cause satiety?	1.2
Lactoferrin	Toxin binding Antimicrobial, antiviral Immunomodulation Anticarcinogenic Antioxidative Iron absorption	0.1
Lactoperoxidase	Antimicrobial	0.03
Lysozyme	Antimicrobial, synergistic with immunoglobulins and lactoferrin	0.0004

Table 11.2 Bioactive peptides derived from cows' milk proteins (Korhonen *et al.*, 1998; Clare and Swaisgood, 2000)

Bioactive peptides	Protein precursor	Bioactivity
Casomorphins	α- and β-Casein	Opioid agonists
α-Lactorphin	α-Lactalbumin	Opioid agonists
β-Lactorphin	β-Lactoglobulin	Opioid agonists
Lactoferroxins	Lactoferrin	Opioid antagonists
Casoxins	κ-Casein	Opioid antagonists
Casokinins	α- and β-Casein	Antihypertensive
Casoplatelins	κ-Casein, transferrin	Antithrombotic
Casecidin	α- and β-Casein	Antimicrobial
Isracidin	α-Casein	Antimicrobial
Immunopeptides	α- and β-Casein	Immunostimulants
Phosphopeptides	α- and β-Casein	Mineral carriers
Lactoferricin	Lactoferrin	Antimicrobial
Glycomacropeptide	Caseins	Anti-stress

as zinc. In many countries, especially in Europe, milk is the principal source of calcium, providing about 60–80% of the total calcium intake. Calcium forms soluble complexes with milk protein, casein, and phosphorus, and is easily absorbed. Milk contains all the vitamins known to be essential to humans. Vitamins A, D, E and K are associated with the fat component of milk. In northern countries where there is a shortage of sunshine in winter, milk and milk fat has traditionally been the major source of vitamin D. Milk also provides water-soluble vitamins (ascorbic acid, thiamin, riboflavin, niacin, pantothenic acid, vitamin B6, folate and vitamin B12) in variable quantities (Miller *et al.*, 2000).

11.3 Fermented milk products

The Scandinavian countries have a long tradition of using fermented dairy products. In the old days, the seasonal variation in milk production led the farms to preserve milk for the cold winter in the forms of butter and its by-product, buttermilk, as well as other traditional fermented milk products (Leporanta, 2001). Later, the industrial production of these products began, and selected product-specific starter cultures became commercially available. The consumption of milk and fermented milks in selected countries in Europe and some other countries is shown in Fig. 11.1. Cultured buttermilks, or fermented milk products as they are also called, are primarily consumed plain, but flavoured varieties are available, too. Mesophilic *Lactococcus lactis* subsp. *lactis/cremoris/diacetylactis* and *Leuconoctoc cremoris* strains are used for fermentation at 20–30ºC for 16–20 h. Starter cultures other than mesophilic lactococci/leuconostoc can also be used for the fermentation of milk drinks. There are products on the market which are fermented with a special strain of lactobacilli (e.g. *L. casei*) or a mixture of several lactobacilli, lactococci and

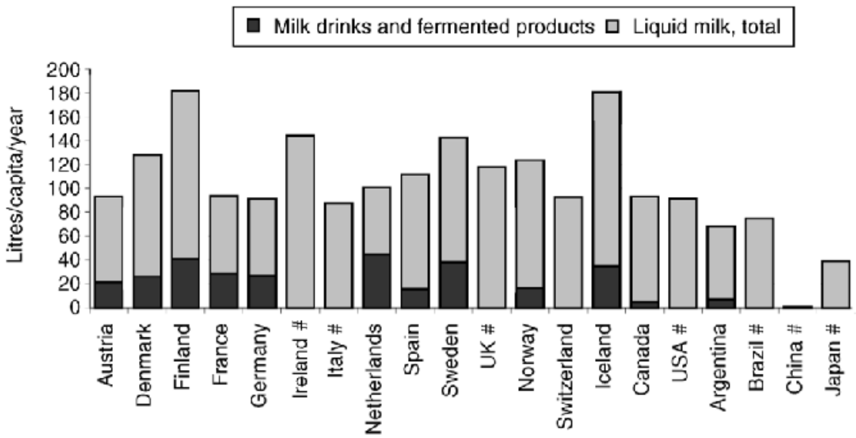

Fig. 11.1 The consumption of milk drinks and fermented products and total consumption of liquid milk in selected countries. #Data not available for fermented products.

other genera/species. For example kefir, a traditional fermented milk drink originating from the Balkans, is produced by a starter culture containing various species of *Lactococcus*, *Leuconostoc*, *Lactobacillus*, *Acetobacter* and yeasts, giving the product its special flavour and aroma.

The health effects of fermented milk products became known through the works of Professor Elie Metchnikoff (Pasteur Institute, Paris), who about a hundred years ago discovered that the secret of the long life of Bulgarian peasants lay in their high consumption of a fermented milk product, yoghurt. Since the 1950s, the flavouring of yoghurt with fruits has increased consumption radically. Today yoghurt is of ever-increasing popularity and there are various types of yoghurt on the market. All yoghurts have this in common: that the milk is fermented with *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*, which grow in synergy in milk. The fermentation is carried out at 30–43ºC for 2.5–20 h. The selection of the starter culture strains defines the fermentation time and thus the structure and flavour of the final product. Fruit preparations may then be added to the fermented milk base before packaging.

Quark-based products (fresh cheeses, etc.) are also made with microbial fermentations of milk, but the whey is separated after milk coagulation. The production processes vary, but many products contain live lactic acid bacteria. Matured cheeses are formed if coagulated milk protein and milk fat are further processed by pressing, salting and maturing in a cool temperature for various periods of time.

All fermented milk products contain live lactic acid bacteria, unless they are pasteurised after fermentation. In 2000 the total consumption of fermented milks and yoghurts in the EU was about 6.35 million tonnes (*Bulletin of the*

International Dairy Federation **368**, 2001). That means a total consumption of more than 10^{20} colony-forming units (cfu) of lactic acid bacteria. Consumption varies considerably according to country, the highest being in the Nordic countries and the Netherlands. Since Metchnikoff's time, fermented milks have been thought to offer health benefits. The addition of selected, well-documented health-effective strains (probiotics) to the fermentations is an easy and natural way of enhancing the functionality of these products. When one considers the healthy nature of milk, consumed on a daily basis, it is hardly surprising that the major part of functional foods is dairy based.

11.4 What do we mean by functional dairy products?

Functional foods are not defined in the EU directives. Some countries (e.g. the UK, Sweden, Finland) have national rules (guidelines on health claims) for the interpretation of the current legislation (Directives 65/65/EEC and 2000/13/EC) in relation to health claims, but as more products are advertised and marketed across borders, harmonisation at the EU level is needed (Smith, 2001). A draft proposal (working document Sanco/1832/2002) is under discussion. In Finland new guidelines were launched in June 2002. The European Functional Food Science Programme, funded by the European Union and led by the International Life Sciences Institute (ILSI), defines functional foods as follows (Diplock, 1999):

> A food can be regarded as 'functional' if it is satisfactorily demonstrated to affect beneficially one or more target functions in the body, beyond adequate nutritional effects in a way that is relevant to either an improved state of health and well-being and/or reduction of risk of disease.

What is actually meant by 'satisfactorily demonstrated'? One of the interpretations is that a food product can be called functional only if its health benefit has been shown in the consumption of a normal daily dose of the final product, or an effective dose of the ingredient is used and the impact of the food matrix is known. There is a general consensus that, in order to be 'satisfactorily demonstrated', at least two high-quality human intervention studies must have been completed.

Dairy foods can be divided into three groups:

- Basic products (milk, fermented milks, cheeses, ice cream, etc.).
- Added-value products, in which the milk composition has been changed, e.g. low-lactose or lactose-free products, hypoallergenic formulae with hydrolysed protein for milk-hypersensitive infants, milk products enriched with Ca, vitamins, etc. Primarily, these products are targeted at specific consumer groups, and, depending on individual opinions, are included or not in the functional food category.

- Functional dairy products with a proven health benefit. Products are based on milk that is enriched with a functional component, or the product is based on ingredients originating from milk. The most common functional dairy products are those with probiotic bacteria, quite frequently enriched with prebiotic carbohydrates.

11.5 Examples of functional dairy products: gastrointestinal health and general well-being

11.5.1 Probiotic products

Probiotic bacteria are live microbial strains that, when applied in adequate doses, beneficially affect the host animal by improving its intestinal microbial balance. **Probiotic foods** are food products that contain a living probiotic ingredient in an adequate matrix and in sufficient concentration, so that after their ingestion, the postulated effect is obtained, and is beyond that of usual nutrient suppliers (De Vrese and Schrezenmeir, 2001).

It is clear, then, that the tradition of fermented dairy products is long, and to make these products 'functional' is a natural and fairly simple concept (Lourens-Hattingh and Viljoen, 2001). The probiotic strains used in dairy products most commonly belong to *Lactobacillus* and *Bifidobacterium* genera (see Table 11.3). The characteristics of probiotic strains vary, and each strain has to be studied individually. The primary requirement of a probiotic strain is that it should be adequately identified with methods based on genetics, and that the strain should be defined in the text of the product package. This makes it possible to analyse the scientific data behind any claims made.

Some probiotic strains are sufficiently proteolytic to grow excellently in milk, but others need growth stimulants. Those that do not ferment lactose need monosaccharides (Saxelin *et al*., 1999; De Vrese and Schrezenmeir, 2001). Sometimes the texture or the taste of a milk product fermented with a probiotic does not meet with consumer approval or is technologically impractical. For this reason it is common to use probiotic strains together with standard starter cultures (yoghurt, mesophilic, etc). Probiotics can be added before the fermentation of the milk, or part of the milk can be fermented separately with the probiotic strain and the two parts mixed after the fermentations.

Table 11.3 The most common species of bacteria used in probiotic dairy foods

• *Lactobacillus acidophilus* group: *L. acidophilus, L. johnsonii, L. gasseri, L. crispatus*	• *Bifidobacterium lactis*
• *L. casei/paracasei*	• *B. bifidum*
• *L. rhamnosus*	• *B. infantis*
• *L. reuteri*	• *B. breve*
• *L. plantarum*	• *B. animalis*
	• *B. adolescentis*

Alternatively, a probiotic strain can be added to the fermented product after fermentation. Sometimes the milk is not fermented at all.

The level of a probiotic strain has to be stable and viable during the shelf-life of the product. There are reports showing that this is not always the case (Shah, 2000). However, research on the subject has changed the situation and will further improve the quality of probiotic products. Today most of the defined probiotic strains used in dairy products have good storage stability. As to the testing of functionality, the easiest method is to develop one type of product and to test its health benefits. Multinational companies often operate in several countries with the same product image marketed under the same trade mark. The small bottle – the 'daily dose' concept – is a good example of this. Identical bottles of Yakult (with the *Lactobacillus casei* Shirota strain) or those of Danone Actimel (with the *L. casei* Imunitass strain DN 114 001) are marketed with the same product concept and the same marketing message all over the world.

However, to meet consumers' demands for probiotic foods in different countries, different types of products are also needed. One way to meet this challenge is to try to define an effective daily dose to be used in various types of products. For example, *Lactobacillus rhamnosus* GG is used in Finland in cultured buttermilks, 'sweet' milk, yoghurts, fermented whey-based drinks, set-type fermented milks ('*viili*'), cheeses, juices, and mixtures of milk and juice. It is not reasonable or scientifically interesting to repeat clinical studies with all the different types, especially when the overall claims to be used in marketing are the same general level. Milk is a protective food matrix for probiotics and improves the survival of the strain in the intestine. As can be seen in Fig. 11.2, if one wishes to re-isolate the strain in stool samples during daily consumption, much lower doses of *Lactobacillus* GG can be used in milk or cheese than in capsules or in powders.

The most common probiotic dairy products worldwide are various types of yoghurt, other fermented dairy products (e.g. cultured buttermilks in Finland), various lactic acid bacteria drinks ('Yakult-type') and mixtures of probiotic (fermented) milks and fruit juice. Probiotic cheeses, both fresh and ripened, have also been launched recently. From January 2000 to May 2002, 25 functional cheeses were launched in Europe, 19 of which, it was claimed, contained an active culture or a probiotic strain (Mintel's Global New Products Database; www.gnpd.com). In addition to everyday products, probiotics are also used in indulgence products, e.g. ice creams.

Probiotic dairy foods (with certain specific strains) are known to relieve intestinal discomfort, prevent diarrhoea and improve recovery. However, no country will accept this claim, as it is too medical for use in the marketing of food. The most common health claim used for probiotic dairy foods may be 'improves natural defence systems', but as far as we know, the science behind that statement is not officially evaluated in any country for any product. In Japan, where functional food legislation is organised best, the package claims for the accepted Food for Specified Health Use (FOSHU) regulation lactobacilli products are that they balance gastrointestinal functions. Recently a claim that a

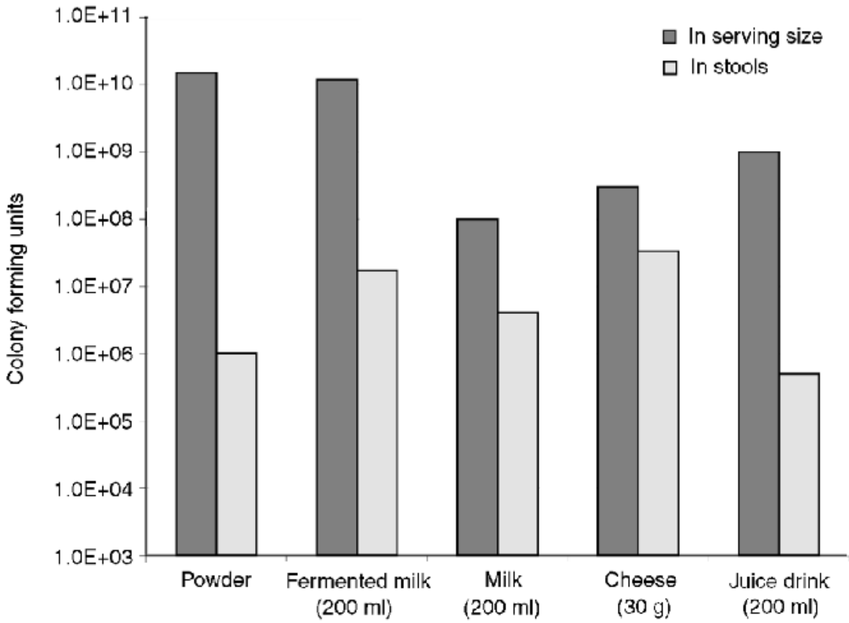

Fig. 11.2 The recovery of *Lactobacillus* GG in faecal samples during daily consumption of different product forms. The daily dose of the probiotic strain (log cfu) per serving and the level in stool samples (log cfu/g wet mass) are indicated in the vertical axis.

yoghurt product enriched with a strain of *L. gasseri* suppressed *Helicobacter pylori* (one cause of peptic ulcers) was also accepted. There are other products that supposedly suppress the growth and activity of *H. pylori*, both in Europe and in the Korean Republic.

11.5.2 Prebiotic and synbiotic dairy products

Prebiotics are non-digestible food ingredients that beneficially affect the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon. **Prebiotic foods** are food products that contain a prebiotic ingredient in an adequate matrix and in sufficient concentration, so that after their ingestion, the postulated effect is obtained, and is beyond that of usual nutrient suppliers. **Synbiotics** are mixtures of pro- and prebiotics that beneficially affect the host by improving the survival and implantation of selected live microbial strains in the gastrointestinal tract (De Vrese and Schrezenmeir, 2001).

In contrast to probiotics, which introduce exogenous bacteria into the human intestine, prebiotics stimulate the preferential growth of a limited number of bacteria already existing in a healthy, indigenous microbiota. The clue to prebiotic compounds is that they are not digested in the upper gastrointestinal tract, because of the inability of the digestive enzymes to hydrolyse the bond between the monosaccharide units. They act as soluble fibres and are digested in the colon, enhancing microbial activity and stimulating the growth mainly of bifidobacteria and lactobacilli. Consumption of higher doses may encourage the formation of gas, flatulence and intestinal discomfort. The end-products in the gut fermentation are mainly short chain fatty acids (acetic, propionic and butyric acid), lactic acid, hydrogen, methane and carbon dioxide. Short chain fatty acids, especially butyric acid, are known to act as an energy source for enterocytes (Wollowski *et al.*, 2001). The main dairy products enriched with prebiotics are yoghurts and yoghurt drinks, but spreads, fresh cheeses and milks are also on the market.

Galactooligosaccharide, a milk-based prebiotic, is derived from lactose by the β-galactosidase enzyme. It is a natural prebiotic of human breast milk, and facilitates the growth of bifidobacteria and lactobacilli in breast-fed infants. Galactooligosaccharides are commercially used principally in Japan and other parts of Asia.

In Europe inulin and fructooligosaccharides are widely used in various functional foods, including dairy-based products. Inulin is a group of fructose polymers linked by β(2–1) bonds that limit their digestion by enzymes in the upper intestine. Their chain lengths range from 2 to 60. Oligofructose is any fructose oligosaccharide containing two to ten monosaccharide units linked with glycosidic linkage. Both inulin and fructooligosaccharides (oligofructoses) are extracted from plant material (e.g. chicory) or synthesised from sucrose. The role of inulin and the oligofructoses in a food matrix is bi-functional. They do not increase the viscosity of a milk product but give a richer texture to liquid products and spreads.

11.5.3 Low-lactose and lactose-free milk products

In the human intestine lactose is hydrolysed by a lactase enzyme developed in the brush border of the small intestine. When a person has a lactase deficiency and lactose causes intestinal discomfort and other symptoms, this is called lactose intolerance, and is quite common in most parts of the world. The incidence of lactose intolerance is low only in the Nordic countries, the British Isles, Australia and New Zealand. Most people can drink one glass of milk (~10 g lactose) in a single dose taken with a meal, without suffering symptoms, but not a 50 g dose ingested on an empty stomach, the dose used in lactose tolerance tests.

There is a general consensus of opinion that probiotic dairy products alleviate lactose intolerance. This is true of all fermented dairy products, especially yoghurt, owing to the β-galactosidase activity of the yoghurt culture and the higher consistency of fermented milks compared with ordinary milk. However, a much more sophisticated and efficient way of reducing symptoms caused by lactose is to hydrolyse it in the milk enzymatically. In long-life milks the enzyme is generally added to the milk after sterilisation, and the product is released for sale after a certain period, when the level of lactose has decreased.

In fermented milks the enzyme is added before fermentation or at the same time as the culture. If added with the culture, the enzyme must be active in acidic conditions. In Finland, Valio Ltd has a large range of lactose-hydrolysed (HYLA®) milk products, altogether around 80 varieties.

The hydrolysis of lactose changes the taste of the milk, making it sweeter, because glucose and galactose are sweeter than lactose. This is an accepted fact in fermented milk products, especially if they are additionally sweetened. However, this sweetness is not popular in milk for drinking, and thus milk consumption drops. Recently, this problem, too, has been solved. In 2001 Valio Ltd launched a lactose-free milk in which the lactose has been completely removed physically. The sweetness has been restored to its normal level and the taste is that of normal fresh milk.

11.5.4 Others

Sphingolipids contain compounds such as ceramides, sphingomyelin, cerebrosides, sulphatides and gangliocides. Sphingolipids are found in millk, butter and cheese – approximately 2 mg/100 g milk. Because they exist in cell membranes rather than in fat droplets, they are found in fat-free, low-fat as well as in full-fat dairy products. *In vitro* and experimental studies indicate that sphingolipids influence cell regulation, and thus carcinogenesis and tumour formation (Miller *et al.*, 2000). In 2000, a yoghurt brand called ‘Inpulse’ was launched in Belgium (Büllenger Butterei). The low-fat product was said to be rich in natural milk lecithin (45 mg/100 g) and sphingolipids (phospholipids 144 mg/100 g). A variety launched since then contains 0.6 g fat, 115 mg phospholipids, 36 mg phosphatidylcholine and 18.4 mg sphingolipids. The information on the product declares that ‘lecitin and sphingolipids are biomembranes, which re-establish the biological equilibrium of the cells, protect against bacterial infections and help digestion’.

11.6 Examples of functional dairy products: cardiovascular health

Coronary heart disease (CHD) is a serious form of cardiovascular disease and the most common – the leading cause of death in developed industrialised countries. Many risk factors, both genetic and environmental, contribute to the development of coronary heart disease. The three most important modifiable risk factors for this are cigarette smoking, high blood pressure and high blood cholesterol levels, particularly of low-density lipoprotein (LDL) cholesterol. Other risk factors likely to contribute to the risk of CHD are diabetes, physical inactivity, low high-density lipoprotein (HDL) cholesterol, high blood triglyceride levels, and obesity. Oxidative stress, homocysteine, lipoprotein and psychosocial factors may also increase the risk. To choose a healthy, low-fat diet with high levels of fruits and vegetables, an active lifestyle and no smoking seems to reduce the risk of heart diseases. The inclusion of semi-skimmed or non-fat milk products in an otherwise healthy diet adds many essential vitamins, not to mention milk calcium, which has a vital role in controlling blood pressure (Miller *et al*., 2000). Milk products specifically developed to reduce dietary risk factors are already on the market.

11.6.1 Products for controlling hypertension

There are a few products on the market for lowering blood pressure. Several milk peptides are known to have an inhibitory effect on the angiotensin converting enzyme (ACE inhibition). ACE is needed for converting angiotensin I to angiotensin II, increasing blood pressure and aldersterone, and inactivating the depressor action of bradykinin. ACE inhibitors derived from caseins are called casokinins, and they are derived from the tryptic digestion of bovine β- and κ-caseins. In two commercial products, these peptides are isoleucine–proline–proline and valine–proline–proline, which are formed from β-casein by the fermentation of milk with *Lactobacillus helveticus*. The *L. helveticus* bacterium is generally used in cheese-making and the fermentation is a normal dairy process. The Calpis Amiel drink (Japan) is a sterile product, without living bacterial cells. The fermented milk drink Evolus, more recently developed by Valio Ltd (Finland), contains, in addition to the active tripeptides, living bacterial cells and an improved composition of minerals (Ca, K, Mg). Both products have been tested in animal studies with spontaneously hypertensive rats (Sipola, 2002) and in clinical human trials (Hata *et al*., 1996; Seppo *et al*., 2003). The Japanese product has official FOSHU status.

In Finland there is a cheese on the market that has been shown to have ACE inhibitory activity (Festivo cheese, Agricultural Research Centre, Jokioinen, Finland). The bioactive peptides are shown to be α_{s1}-casein N-terminal peptides but the researchers thought that they might be too long to be absorbed intact in the intestine. The quantity also varied during the maturation and age of the cheese, and the effect of the cheese on human blood pressure remains to be tested (Ryhänen *et al*., 2001). Another idea, not yet commercially launched in dairy products, is based on whey proteins that are hydrolysed so that the whey protein isolate has an ACE inhibitory activity (Davisco Foods International Inc., USA). The effect of this product seems to be much faster than those based on the tripeptides, but the mechanism is not yet known (Pins and Keenan, 2002).

11.6.2 Products for controlling cholesterol

Natural cows' milk fat contains high levels of saturated fatty acids. Replacing the consumption of full-cream milk with semi-skimmed or non-fat milk will reduce the intake of saturated fatty acids. Sometimes it is not enough just to reduce the intake of saturated fats and cholesterol, since most cholesterol is synthesised within our own bodies. On the other hand, plant sterols and stanols have long been known to reduce the assimilation of dietary cholesterol. Since the mid-1990s there have been products enriched with plant stanols specially targeted at those people with (moderately) high cholesterol levels. A few years later plant sterols were also accepted as food ingredients by the EU Novel Foods legislation, and now the Food and Drug Administration in the USA has also accepted plant sterols and stanols. Sterols are building blocks of the cell membranes in both plant and animal cells. Isolated plant stanols, hydrated forms of sterols, are crystallised particles. They effectively bind cholesterol and are not absorbed by the human body. Esterified plant stanols are fat-soluble and easy to use as a food ingredient. Intestinal enzymes hydrolyse the ester bond and the insoluble stanol is free to bind cholesterol and to be secreted. Basically, the effect of plant sterols is based on the same mechanism.

Several milk-based functional foods including plant sterols or stanols are commercially available. They all are semi-skimmed or non-fat products. Products containing Benecol (Raisio Benecol Ltd, Finland), the only **plant stanol** ester ingredient, are on the market in several countries. In some products the 'effective daily dose' has to be collected from several servings (e.g. Benecol milk, yoghurt, various spreads in the UK), in some other countries the dose is contained in one serving (e.g. Valio Benecol yoghurt in Finland). **Plant sterols** are also added to functional milk products, especially to milk (e.g. Mastellone Hnos SA, Argentina). In March 2001, Marks & Spencer launched a range of 20 products, including yoghurt, enriched with **soy proteins** (& More brand, UK). The daily consumption of 25 g soy proteins has been shown to lower cholesterol by 10%.

The safety risk of overdosing with plant sterols and stanols has been the subject of discussion by the scientific committee on food of the European Commission. The consumption of this kind of product requires a fairly good knowledge on the part of the consumer, as she or he has to be familiar with the products with the compound and also to know the quantity of the active ingredient in various products. For that reason the labelling must be informative enough.

Matured cheeses contain quite high levels of milk fats. Replacing milk fat with vegetable oil can reduce the intake of saturated fatty acids. In Finland there are cheeses on the market in which milk fat has been replaced by rapeseed oil (Julia and Julius with 17% and 25% rapeseed oil, respectively; Kyrönmaan Osuusmeijeri, Finland). The products, when included daily in a low-fat diet, reduced blood cholesterol statistically significantly (Karvonen *et al.*, 2002).

11.6.3 Omega-3 fatty acids

There are two major classes of polyunsaturated fatty acids: omega-3 fatty acids found in fish oils and as a minor constituent of some vegetable oils, and omega-6 fatty acids, which include the essential fatty acid linoleic acid, found in vegetable oils such as corn, sunflower and soybean. Omega-3 fatty acids are said to contribute to the good functioning of the cardiovascular system, on the basis of various physiological effects. Before omega-3 fatty acids could be added to milk products, the fishy taste and odour had to be disguised and the easy oxidation of the oil overcome. It took several years before these problems were solved, but nowadays there are a few suppliers selling good-quality fish-oils to be added to milk. The pioneer in launching an omega-3-enriched milk was the Italian dairy company Parmalat. Its 'Plus Omega 3' milk was launched in 1998 and is a semi-skimmed milk enriched with 80 mg omega-3. It is recommended for use by all health-conscious consumers in a dose of half a litre per day (Mellentin and Heasman, 1999). Since then other producers all over the world have followed with their own omega-3-enriched milks. Milk is often also enriched with the antioxidative vitamins A, C and E.

11.7 Examples of functional dairy products: osteoporosis and other conditions

The cause of osteoporosis, as with other chronic diseases, is multifactorial, involving both genetic and environmental factors. An accumulation of scientific evidence indicates that a sufficient intake of calcium throughout one's life offers protection against osteoporosis. The bone mass reaches its peak when a person is 30 years of age and then the density decreases with age, especially after the menopause. The fortification of semi-skimmed and non-fat milk with vitamin D is important, as this vitamin is essential to improve calcium absorption and is also removed when fat is removed. Milk is the richest source of calcium. There are several milks and milk products enriched with calcium, and both inorganic and milk-based calcium (e.g. TruCal, Glanbia Ingredients Inc.) are used. The absorption of calcium may be enhanced with bioactive milk proteins. Caseinophosphopeptides (CPPs) are known to increase the solubility of calcium, but controversy exists as to whether CPPs enhance calcium absorption in the body. The authors do not know of any commercial applications of CPPs in dairy products.

11.7.1 Products for enhancing immune functions

Some of the probiotic dairy products have been shown to enhance immune functions and thus to reduce the risk of infection. Milk contains natural immunoglobulins, which can be isolated and concentrated, either from normal milk or from colostrum, which contains a high proportion of them. There are milk-based products on the market in which the product is further enriched with immunoglobulins. In the USA and Australia, Lifeway Foods is marketing kefir under the brand name Basic Plus. The product is said to be probiotic, although the probiotic strains are not specified. The active ingredient, an extract of colostrum, has been developed by GalaGen Inc. and is targeted at maintaining intestinal health and the natural microbiota. Basic Plus was launched in 1998 and is the first dairy-based food supplement sold in the USA in the refrigerated sections of health food and grocery stores.

Milk immunoglobulins are used in new drinks in the USA under the brand name of ‘NuVim’. The production of immunoglobulins is boosted in a selected herd in New Zealand by an immune stimulant, and isolated under carefully controlled conditions in order to preserve the micronutrients. The product is said to be lactose-free and fat-free, to have beneficial effects on the immune system and to improve the health of muscles and joints (Heasman and Mellentin, 2002).

11.7.2 Milks to help with sleeping problems

Melatonin is a hormone that controls the body’s day and night rhythm. The secretion of melatonin is high in early childhood and decreases rapidly with ageing. Stress conditions and age cause a lowering of the level of melatonin. It is secreted at nights in both humans and bovines. The concentration at night in cows’ milk is about four times higher than in milk collected during the day. The first product based on a standardised milking system at night was launched in Finland in 2000 (Yömaito, Ingman Foods Ltd). Since no human trials have been published so far, the company does not make any health claims. In spring 2002 an organic milk, ‘Slumbering Bedtime Milk’ (Red Kite Farm, UK), was launched in the UK. It is said to contain higher levels of melatonin than ordinary milk. The company says that the level of melatonin in the milk complements that of the human body and the drink will not induce drowsiness if drunk during the day, or the following morning if drunk at night/late in the evening.

11.8 Future trends

Research and discussion on pro- and prebiotics have encouraged basic research in the field of the intestinal microbial flora and its metabolism. This has also led to improved research funding from public resources, both nationally and from the European Union. Not enough is known of the composition and metabolism of the bacteria in the intestines in health and disease. Also the knowledge on the role of the microbiota in the development and function of immune response needs more investigation. Development and improvements in research methods, and *in vitro*, *ex vivo* and *in vivo* models, have provided important information on the mechanisms behind the effects, and new biomarkers to be followed in human studies. The more we know about the composition and function of the intestinal microbiota, the greater the potential to develop functional foods for targeted consumer groups. Considering the healthy population there may be potential to develop targeted products for different age groups. In the reduction of risk and treatment of various diseases, pro- and prebiotics have resulted in promising benefits. However, it is important to understand the mechanisms behind the effects. When the mechanisms are known, it will be also possible to control the activity or the dose of the effective compounds. We also need official definitions of functional foods, and relevant regulation of physiological claims and health claims. The production of functional foods that have to follow the rules of production of medicines is hardly in the interest of normal dairy companies. It may be unrealistic to apply the same rules to medicines as to everyday foods with a short shelf-life.

Milk is a rich source of nutritive compounds which can be enriched and/or further modified. Milk fat does not consist merely of saturated fatty acids, but also of monounsaturated and polyunsaturated fatty acids. The role of conjugated linoleic acid (CLA) in preventing the risk of certain diseases, and in particular, the problem of how to increase its quantity in milk has evoked wide interest among several research groups. Milk proteins and bioactive peptides may supply new products to help protect against several common health risk factors. There are bioactive peptides potentially to be used to give satiety or to better tolerate stress. Lactose derivatives can be used as soluble fibre to relieve constipation and to modulate the intestinal flora. Milk minerals can be used to replace sodium in salt, supporting a healthy diet for avoiding hypertension. Milk components are natural, and applications for novel foods are seldom needed. There is also a huge selection of lactic acid bacteria used for milk fermentations, which have a long tradition of safe use. Genetically modified strains may be needed for special purposes, though perhaps not in products for the general public.

In developing functional dairy products, various groups of experts are needed. The basis must be in the scientific research of effects, requiring medical experts, nutritionists and microbiologists. Food technologists are needed for product development, process technologists and biotechnologists for processing the compounds, chemists to analyse the compounds and, finally, experts for marketing the products. Marketing is a big challenge, as it has to tell the public about the health benefits in such a simple way that every layperson understands. Medical and nutritional messages need to be simplified. It is important to remember that functional dairy products are mainly for supplying nutritive foods for everyday consumption. Nutrimarketing is also needed to explain research results to health-care professionals and to convince them of the benefits of functional foods.

11.9 Sources of further information and advice

www.gnpd.com
www.new-nutrition.com
www.scirus.com
www.just-food.com
www.ifis.org
http://www.foodlineweb.co.uk
www.fst.ohio-state.edu/People/HARPER/Functional-foods/Functional-Foods.htm
www.valio.com
www.benecol.com
www.daviscofoods.com
www.kefir.com

www.ific.org
www.effca.com
www.usprobiotics.org
www.elintarvikevirasto.fi/english

11.10 References

BANKS W and DALGLEISH D G (1990), 'Milk and milk processing' in Robinson R K, *Dairy Mircobiology*, Volume 1, *The Microbiology of Milk*, second edition, London, Elsevier Science Publishers Ltd, 1–35.

CLARE D A and SWAISGOOD H E (2000), 'Bioactive milk peptides: a prospectus', *J Dairy Sci*, **83**, 1187–1195.

DE VRESE M and SCHREZENMEIR J (2001), 'Pro and prebiotics', *Innov Food Technol*, **May/June**, 49–55.

DIPLOCK A T (1999), 'Scientific concepts of functional foods in Europe: Consensus document', *Br J Nutr*, **81**(Suppl 1), S1–S27.

HATA Y, YAMAMOTO M, OHNI M, NAKAJIMA K, NAKAMURA Y and TAKANO T (1996), 'A placebo-controlled study of the effect of sour milk on blood pressure in hypertensive subjects', *Am J Clin Nutr*, **64**, 767–771.

HEASMAN M and MELLENTIN J (2002), 'New NuVim prepares to be swallowed up', NNB, 7(8), 29–30.

KARVONEN H M, TAPOLA N S, UUSITUPA M I AND SARKKINEN E S (2002), 'The effect of vegetable oil-based cheese on serum total and lipoprotein lipids', *Eur J Clin Nutr*, **56**, 1094–1101.

KORHONEN H, PIHLANTO-LEPPÄLÄ A, RANTAMÄKI P and TUPASELA T (1998), 'Impact of processing on bioactive proteins and peptides', *Trends Food Sci Technol*, **8**, 307–319.

LEPORANTA K (2001), 'Developing fermented milks into functional foods', *Innov Food Technol*, **10**, 46–47.

LOURENS-HATTINGH A and VILJOEN B C (2001), 'Yoghurt as probiotic carrier food', *Int Dairy J*, **11**, 1–17.

MELLENTIN J and HEASMAN M (1999), 'Functional foods are dead. Long live functional foods', *NNB*, **4**(7), 16–19.

MILLER G D, JARVIS J K and MCBEAN L D (2000), *Handbook of Dairy Foods and Nutrition*, second edition, Boca Raton, London, New York, Washington DC, CRC Press.

PINS J and KEENAN J M (2002), 'The antihypertensive effects of a hydrolysed whey protein isolate supplement (BioZate 1®)', *Cardiovasc Drugs Ther*, **16** (Suppl 1), 68.

RYHÄNEN E-L, PIHLANTO-LEPPÄLÄ A and PAHKALA E (2001), 'A new type of ripened, low-fat cheese with bioactive properties', *Int Dairy J*, **11**, 441–447.

SAXELIN M, GRENOW B, SVENSSON U, FONDEN R, RENIERO R and MATTILA-SANDHOLM T (1999), 'The technology of probiotics', *Trends Food Sci Technol*, **10**, 387–392.

SEPPO L, JAUHIAINEN T, POUSSA T and KORPELA R (2003), 'A fermented milk, high in bioactive peptides, has a blood pressure lowering effect in hypertensive subjects', *Am J Clin Nutr*, **77**, 326–330.

SHAH N P (2000), 'Probiotic bacteria: selective enumeration and survival in dairy foods', *J Dairy Sci*, **83**(4), 894–907.

SIPOLA M (2002), 'Effects of milk products and milk protein-derived peptides on blood pressure and arterial function in rats', PhD Thesis, Institute of Biomedicine/Pharmacology, University of Helsinki; electronic PDF version: http://ethesis.helsinki.fi/julkaisut/laa/biola/vk/sipola/.

SMITH J (2001), 'Defining health claims for Europe', *Funct Foods Nutraceut*, **November/December**, 12.

WOLLOWSKI I, RECHKEMMER G and POOL-ZOBEL B L (2001), 'Protective role of probiotics and prebiotics in colon cancer', *Am J Clin Nutr*, **73**(2 Suppl), 451S–455S.