CHAPTER 19

Dietary Foods

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INTRODUCTION

Nutraceuticals find therapeutic application in a wide range of food products. These include foods and drinks enriched or fortified with vitamins, minerals, fatty acids, proteins and amino acids, fiber, plant phytochemicals, probiotic bacteria, fruit extracts, traditional spices, and herbal ingredients. These products could have a key role to play in health enhancement and/or disease risk reduction in the 21st century. In the developed world, a high proportion of the diet is derived from processed and convenience foods. In this context, specific dietary foods and drinks appropriate for an individual’s lifestyle, health status, and genotype could make an important contribution to a healthy diet.

Moreover, demographic change, an increasing incidence of degenerative diseases, many as the result of the global obesity epidemic, and the concomitant rise in the costs of healthcare are increasing the pressure to shift from treatment to prevention. This change in emphasis could include the substitution of dietary foods for drugs to provide specific health benefits. Examples of currently available food ingredients that have shown some promise and could potentially be used as substitutes or partial replacements for drugs (depending on the generation of an adequate evidence base) include the following:

- Beta-glucan for controlling blood glucose as a substitute for oral hypoglycemic drugs and insulin
- Probiotic bacteria (instead of antidiarrheal drugs) for diarrhea
- Probiotics as potential substitutes for aminosalicylates and corticosteroids in the management of IBD (e.g., Crohn’s disease, ulcerative colitis)
- Probiotics to assist in the eradication of Helicobacter pylori together with acid suppressant and antibiotic therapy
- Prebiotics instead of laxatives in the management of infrequent bowel function
- Bioactive peptides as substitutes for antihypertensive medication in the management of high blood pressure
- Phytosterols, soy proteins, and soluble fiber as substitutes for statins in cholesterol lowering
- Chitosan or CLA as substitutes for orlistat and other antiobesity drugs
- Omega-3 fatty acids for mental health conditions (e.g., depression, schizophrenia) instead of antidepressants and antipsychotics
- Melatonin for promotion of sleep instead of benzodiazepines

A dietary approach is financially logical for healthcare systems in that foods are not only cheaper than medicines but are also purchased by consumers rather
than by the government or the insurer [Institute of Grocery Distribution 2003]. This trend toward self care is already apparent, partly as a reaction against conventional medicine but also because many individuals feel good about taking control of their health. Dietary change, including the consumption of dietary foods, can represent one form of self care. However, this shift to self care requires educated and informed consumers. Individuals need to know what dietary actions they should be taking, as do the professionals who advise them. This requires an effective evidence base around the benefits of specific foods for specific individuals and population groups. There is therefore a need for the food industry to demonstrate that individual foods consumed in normal amounts can improve health or influence disease occurrence.

**THE MARKET**

The market for dietary foods and supplements is large, although the year-to-year increase appears to have slowed somewhat in recent years. A recent report found that the so-called “functional foods” sector increased worldwide by 8.3% in value terms in the year to September 2007, a substantial slowing of growth from the 22.1% rise shown in the year to September 2006 [Key Note Publications 2008]. This was accounted for by a decline in sales of probiotic yogurt drinks, whereas sales of cholesterol-lowering spreads increased only slightly. However, there was positive growth in probiotic yogurts, soya milks, and fortified breakfast cereals. A recent Mintel report noted that the U.K. functional foods sector grew by only 3% in 2007 compared with more than 20% in 2006 [Mintel 2008], yet Mintel still predicted a U.K. growth of 72% between 2007 and 2012, with sales increasing from £613 million to £1 billion over this five year period [Mintel 2008].

**DEFINITIONS**

Dietary foods encompass an enormous range of products, usually produced by adding nutraceuticals, including nutrients and other potentially health-promoting ingredients, and/or by removing or reducing potentially less healthy ingredients (e.g., saturated fat, sugar, salt). Increasingly, this term is also used to include those conventional foods that are promoted for their favorable nutritional properties but have no added ingredients. Oats, for example, are marketed on the basis of their soluble fiber content, whereas certain breakfast cereals are promoted for their whole-grain and fiber content.

Such foods can be regarded as products eligible for health claims. This helps to improve product marketability and communication of potential health and therapeutic benefits to the consumer. Dietary foods produced for this purpose are variously categorized as “functional foods,” “designer foods,” “vita foods,” “medifoods,” “alicaments,” and “pharmafoods.”

There is no consensus on the definition of any these terms, but collectively they refer to foods and beverages constructed to confer health and/or therapeutic benefits beyond the nutritional value of the foods themselves. In the early 1990s, the term...
“nutraceutical” might have been included in this category because it was originally defined as a “food (or part of a food) that provides medical or health benefits, including the prevention and/or treatment of a disease” [DeFelice 2002]. In 1999, however, whole foods were distinguished from the natural bioactive compounds derived from them by using the term functional foods to describe the former and nutraceuticals to describe the latter [Zeose 1999]. Under this newer definition, nutraceuticals are functional ingredients derived from foods and are formulated as powders, pills, and other pharmaceutical forms not generally considered to be foods. However, this definition does not exclude the possibility that nutraceuticals can be extracted from some conventional foods (e.g., berry extracts, fish oils) and then added to other food products to produce so-called functional foods. In such cases, the food product could be described as a functional food, the added ingredient as a nutraceutical.

None of these terms has any regulatory definition. The term nutraceutical, for example, is not recognized by the FDA or the European Scientific Committee on Food. Moreover, some nutraceuticals or functional ingredients are sold as supplements or ingredients for potential addition to foods in some countries, whereas in other countries these substances are sold as drugs requiring medical prescription.

In contrast to a nutraceutical or dietary supplement, a functional food is a food or drink product consumed as part of the daily diet [Scientific concepts of functional foods in Europe 1999; Halstead 2003]. Functional foods cannot easily be defined because they are not single, well-characterized entities, although many definitions have been produced. These definitions range from simple statements, such as “foods that may provide health benefits beyond basic nutrition” and “foods marketed with the message of benefit to health” to more complex definitions, such as “foods derived from naturally occurring substances consumed as part of the daily diet and possessing particular physiological benefits when ingested” or “foods that encompass potentially helpful products, including any modified food or food ingredient that may provide a health benefit beyond that of the traditional nutrient it contains” [Roberfroid 2002]. The term functional food covers a wide variety of food products, with a variety of components, both nutrients and non-nutrients, influencing a range of body functions associated with health and/or reduction in disease risk. It has been argued that functional food should therefore be understood as a concept rather than a term to be defined [Roberfroid 2002].

The concept of functional foods was developed in Japan. During the early 1980s, the Japanese government funded research studies to evaluate the functionalities of various foods. This was followed in 1991 by the establishment of a Foods for Specified Health Uses (FOSHU) system, designed to introduce a legal category of foods with potential benefits as part of a national effort to control the escalating costs of healthcare [Omaha, Ikeda, and Moriyama 2006]. According to the Japanese Ministry of Health, Labour, and Welfare, FOSHU include the following:

- Foods that are expected to have a specific health effect attributable to relevant constituents or foods from which allergens have been removed are considered FOSHU.
- Also included are foods in which the effect of such addition or removal has been scientifically evaluated and permission is granted to make claims regarding their specific beneficial effects on health.
To be identified as FOSHU, evidence is required that the final food product, but not isolated individual components, is likely to exert a health or physiological effect when consumed as part of an ordinary diet. FOSHU foods should be in the form of ordinary foods (i.e., not tablets or capsules).

The functional food concept has been further developed in the United States and in Europe. In the 1990s, the International Life Science Institute in Europe developed a functional food project designed to assess the state of the art in functional foods. Known as Functional Food Science in Europe (FUFOSE), this European Commission concerted action involved large numbers of European experts in nutrition and related sciences, who elaborated, for the first time, a global framework that included a strategy for the identification and development of functional foods and for the scientific substantiation of their effects to justify health-related claims [Scientific concepts of functional foods in Europe 1999].

According to this European consensus, 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 to the reduction of risk of a disease. In this context, target function refers to genomic, biochemical, physiological, or behavioral functions [Roberfroid 2002]. According to this consensus, the unique features of functional foods are as follows [Scientific concepts of functional foods in Europe 1999]:

- Are conventional or everyday food
- Are consumed as part of the normal diet
- Are composed of naturally occurring component(s), sometimes in unnatural proportions
- Have a positive effect on the target function beyond nutritive value
- May enhance well-being and health and/or reduce the risk of disease to provide health benefits so as to improve quality of life, including physical, psychological, and behavioral performances
- Have authorized and scientifically substantiated health claims

The FUFOSE document emphasizes the food nature of functional foods. They are not tablets or capsules or any form of dietary supplement but are consumed as part of a normal dietary pattern and must demonstrate their effects in amounts that can normally be expected to be consumed in the diet. Beneficial effects must be demonstrated to the satisfaction of the scientific community and can be used to justify health claims, an enhanced function claim, or a disease risk reduction claim [Roberfroid 2002]. In essence, therefore, functional foods can be regarded as food products eligible for health claims.

LEGISLATION AND CLAIMS

Legislation throughout much of the world does not recognize functional foods as a distinct category of foods, as for example in Japan. This means that functional foods must comply with all relevant food legislation with respect to composition,
labeling, and claims. Claims fall into two categories: medicinal claims and health claims. A medicinal claim states or implies that a food has the capacity to treat, prevent, or cure human disease or makes reference to such a property. Medicinal claims are currently prohibited worldwide for food and drink products. However, in a few cases, medicinal licenses have been granted for certain food supplements (e.g., folic acid may prevent neural tube defects).

A health claim is a direct, indirect, or implied claim in food labeling, advertising, and promotion indicating that consumption of a food carries a specific health benefit (e.g., dietary fiber can help maintain a healthy gut) or reduces the risk of a specific health detriment or disease risk factor (e.g., soy protein can help reduce LDL cholesterol). Health claims have been allowed in the United States since 1993 on certain foods. These contain components for which the FDA has accepted there is objective evidence for a correlation between nutrients or foods in the diet and specific disease risks on the basis of “the totality of publicly available scientific evidence” and in which there is substantial agreement among qualified experts that the claims were supported by the evidence. Twelve types of food components are currently approved by the FDA to make health claims [U.S. Food and Drug Administration 2008].

In Europe, until recently, there has been no harmonized legislation on health claims, and claims have been dealt with at a national level. However, health claims legislation has recently been passed in the European Union, and foods outside of the scope of the medicinal law will be able to make health claims and reduction of disease risk claims, following scientific evaluation by the European Food Safety Authority. An approved list of claims is expected by 2010.

DEVELOPMENT OF FUNCTIONAL FOODS

The following can be considered a functional food:

- A food to which a component(s) has been added during the processing stage to provide benefits. This component(s) can be an officially recognized nutrient (e.g., the addition of folic acid to reduce a woman’s risk of having an infant with a neural tube defect or calcium to contribute to bone health), a non-nutrient (e.g., soluble fiber to promote heart health, phytosterol to reduce serum cholesterol, probiotic bacteria to improve GI health), or an herb (e.g., Ginkgo biloba or ginseng to improve alertness, Echinacea to support the immune system).
- A food from which a component has been removed so that the food has reduced adverse health effects (e.g., the reduction of trans fatty acids by the removal of partially hydrogenated vegetable oil, or the reduction in saturated fatty acids by substitution with monounsaturated or polyunsaturated fatty acids or reduction in total fat).
- A natural food in which one of the components has been naturally enhanced through special growing conditions. For example, can the antioxidant content of plant foods be increased through genetic modification?
- A natural food in which a new component has been introduced through special growing conditions. For example, the European Lipgene project includes work on
the introduction of genes from marine algae into rapeseed plants to enable the synthesis and accumulation of EPA and DHA [Napier and Sayanova 2005]. If this project is successful, this technique could provide an alternative for incorporating long-chain omega-3 fatty acids into functional foods.

- A food in which the bioavailability or stability of one or more components has been increased to provide greater bioavailability of a beneficial component. Selection of raw materials and optimization of processing conditions needs to be carefully studied to enhance the retention of minerals, the bioactivity of proteins and peptides, and beneficial effects of components such as nondigestible carbohydrates, resistant starch, and fat replacers. The study of fermentation processes in both food components and the GI tract is key to the development of probiotics with increased resistance to the environment within the GI tract. The development of effective prebiotics (e.g., nondigestible oligosaccharides) with optimal colonic fermentation rates for health benefits will depend on the evaluation of bioconversion processes and the monitoring of their fermentation in the gut.

- A food in which the nature of one or more components has been chemically modified to improve health (e.g., infant formulas containing hydrolyzed protein to reduce the risk of allergenicity)

- Any combination of the above.

Development of a functional food demands a thorough understanding of basic body functions and the identification of one or more food components that could target a function (i.e., genomic, biochemical, physiological, or behavioral) to improve or maintain health and/or reduce risk of disease. Such potential interactions between the food component and the target function should be plausible and a possible mechanism of action proposed. Biomarkers relevant to the target functions being considered also need to be identified and validated. These could be metabolites, specific proteins, hormones, or enzymes, physiological parameters (e.g., blood pressure, heart rate, GI transit time, etc.), or changes in physical and intellectual performance using objective parameters [Roberfroid 2002]. The proposed functional effect then needs to be demonstrated in carefully designed studies, using these validated markers. Studies should include establishment of effective dose and a safety assessment. The functional food should then be fully developed and, finally, evaluated in a controlled clinical study.

**THERAPEUTIC USES FOR FUNCTIONAL FOODS**

Functional foods (of which some examples are shown in Table 19.1) are available for use in several specific health concerns, of which the following are key:

- Cardiovascular health
- GI health
- Oxidative stress
- Weight management
- Diabetes
- Cognitive/mental health
- Joint and bone health
Cardiovascular Health

Cardiovascular diseases (CVD) are a group of degenerative diseases affecting the whole cardiovascular system, including coronary heart disease, peripheral artery disease, and stroke. To understand the role that functional foods could play in these conditions, it is essential to identify the risk factors for CVD. These include elevated serum cholesterol levels, particularly LDL cholesterol, oxidative modification of LDL cholesterol, low concentration of HDL cholesterol, high blood pressure, high homocysteine levels, damage to the artery lining, compromised endothelial function, and increased blood clot formation.

Fatty Acids

Altering the amounts and proportions of fatty acids in the diet can influence the levels of blood lipids and warrants particular attention in preventing and treating CVD. Saturated fatty acids with chain lengths up to 16 carbon atoms increase plasma LDL cholesterol; they also increase plasma HDL concentration but only to a small extent [Lichtenstein et al. 1998]. Unsaturated fatty acids in the trans configuration that are formed during some manufacturing processes (rather than those trans fatty acids formed from hydrogenation in ruminant animals and found in dairy products and meat) can increase plasma LDL and reduce HDL cholesterol [Erkkila et al. 2008]. Diets low in saturated fatty acids and trans fatty acids could therefore reduce the risk of CVD.

The cis-unsaturated fatty acids, including the mono-unsaturates (e.g., oleic acid found in olive oil) and the poly-unsaturates (e.g., linoleic and ALA) reduce plasma LDL concentrations, and some do this without significantly lowering the beneficial HDL cholesterol [Erkkila et al. 2008]. Olive oil has been the subject of many research studies for its antioxidant, anti-inflammatory, and antithrombic properties in reducing CVD risk [Perez-Jimenez et al. 2007]. The long-chain omega-3 fatty acids (EPA and DHA) found in fish oils can reduce plasma triacylglycerols, counteract blood clotting, and promote improvements in arterial and endothelial integrity. Functional foods enriched in these unsaturated fatty acids could reduce CVD risk.

Soluble Fiber

Soluble fiber appears to influence both hepatic cholesterol and lipoprotein metabolism, thus increasing bile loss. Soluble fiber can reduce LDL concentrations, particularly in people with high levels. Other suggested benefits of soluble fiber include inhibition of hepatic fatty acid synthesis by colonic fermentation products, increase in intestinal motility, and a slowing of macronutrient absorption leading to lowering of the glycemic response and improved insulin sensitivity [Salas-Salvado et al. 2006; Theuwissen and Mensink 2008]. Soluble fiber sources currently used in functional foods include psyllium and dietary fructans (e.g., inulin, oligofructose), both of which have beneficial effects on cardiovascular risk factors [Brighenti 2007;
However, new functional fiber sources could potentially be generated by upgrading raw materials and by products that are rich in carbohydrates, using extraction and fractionation techniques. The challenge exists to modify the cell wall matrix of raw plant materials to alter the binding of water, bile salts, and macronutrients to optimize the glycemic index.

**Phytosterols**

Phytosterols (plant sterols and stanols) are present in many fruits, vegetables, nuts, seeds, legumes, cereals, vegetable oils, and other plant sources. These substances have been shown in numerous studies to reduce plasma LDL concentration by an average of 10% and are thought to act by reducing intestinal cholesterol absorption [Ortega, Palencia, and Lopez-Sobaler 2006]. Most studies have investigated the effect of phytosterols administered in a fat spread vehicle. However, giving phytosterols in other vehicles such as low-fat milk [Clifton et al. 2004; Thomsen et al. 2004; Noakes et al. 2005], yogurt [Mensink et al. 2002; Noakes et al. 2005; Korpela et al. 2006], low-fat cheese [Korpela et al. 2006], low-fat cheese [Korpela et al. 2006], orange juice [Devaraj, Sutret, and Jialal 2006], and a lemon-flavored drink or egg white has also been shown to reduce serum cholesterol [Spilburg et al. 2003]. In addition, combining phytosterols with statins has shown to have an additive effect on cholesterol lowering [Normen, Holmes, and Frohlich 2005].

**Flavonoids**

Flavonoids represent a diverse range of polyphenolic compounds, including flavonols, flavones, flavanones, flavan-3-ols, isoflavones, anthocyanins, and proanthocyanidins, found naturally in plant foods (e.g., fruits, vegetables, grains, herbs, and beverages). Diets high in plant foods and rich in polyphenols have been inversely associated with risk for CVD and other chronic diseases, which may be explained by their range of biological activities observed in vitro, including anti-inflammatory, vasodilatory, antiplatelet and antioxidant effects, and induction of apoptosis [Hooper et al. 2008].

Depending on processing, flavonoids can be particularly abundant in cocoa and chocolate, tea, soy, and red wine, foods and beverages that are increasingly promoted as functional foods in their own right. Dark chocolate is formulated with a higher percentage of cocoa bean than milk chocolate and therefore often contains greater quantities of flavonoids. Dark chocolate has been associated with antioxidant effects, such as reduced susceptibility of LDL cholesterol to oxidation, and with improvements in endothelial dysfunction and lowering of blood pressure [Keen et al. 2005; Engler and Engler 2006; Erdman et al. 2008], but studies have not consistently demonstrated a favorable effect on cholesterol levels. In addition, there are no epidemiological studies specifically evaluating the effect of chocolate and CVD risk. There is a need for prospective cohort studies and additional randomized clinical trials to investigate the long-term impact of chocolate on CVD risk and outcomes. Tea (green, black, and oolong tea) has also been associated with reduced cardiovascular risk, particularly
with improved endothelial function [Stangl, Lorenz, and Stangl 2006; Hodgson et al. 2008].

**Soy Protein**

Products containing soya protein and soya-enriched diets have been shown to reduce both total and LDL cholesterol in many studies in animals and humans with raised cholesterol levels. However, recent studies have suggested that effects on serum cholesterol are much smaller than previously thought [Sacks et al. 2006]. Nevertheless, many soy products should be beneficial to cardiovascular and overall health because of their high content of polyunsaturated fats, fiber, vitamins, and minerals and low content of saturated fat.

**B Vitamins**

High plasma homocysteine is associated with increased risk of CVD. Folic acid and vitamins B_6_ and B_12_ have the potential to lower homocysteine and therefore reduce cardiovascular drink. However, clinical trials evaluating the effect of these B vitamins on cardiovascular outcomes have not been promising [Clarke et al. 2007].

**Gastrointestinal Disease**

The GI tract plays a major role in maintaining health and reducing disease risk. This is achieved by the complex microbial environment that, when in healthy balance, helps to prevent invasion of pathogenic bacteria and maintain the integrity of the immune system so reducing the risk of infection and severe allergic reaction. However, the gut microflora can play an important role not only in infection and allergy but also in constipation, irritable bowel syndrome, IBDs, and, possibly, colorectal cancer. The main groups of GI health-promoting bacteria are the *Bifidobacteria* and the *Lactobacilli*.

**Probiotics**

Probiotics are defined as live microbial food ingredients that, when ingested in sufficient amounts, exert health benefits to the consumer. The main bacteria used as probiotics are various species of *Lactobacilli* and *Bifidobacteria*. They are commonly used in yogurts and fermented dairy drinks. Major health benefits include reduction in the incidence or severity of GI infections (particularly antibiotic associated diarrhea, rotavirus, and traveler’s diarrhea) and alleviation of lactose intolerance [Zuccotti et al. 2008]. There is some evidence, which requires confirmation in additional trials, that probiotics help in the management of inflammatory bowel conditions, such as ulcerative colitis, Crohn’s disease, and irritable bowel syndrome [Hedin, Whelan, and Lindsay 2007]. Regular probiotic consumption may also afford some protection against developing bowel cancer. Optimizing gut microflora with probiotics may also reduce the risk of allergic disease by improving the barrier to antigen penetration.
and/or by stimulating anti-allergenic immunological processes. There is evidence that probiotics can reduce the risk of development of atopic eczema in infants [Furrie 2005], but evidence for a protective effect in asthma and allergic rhinitis is weaker. Probiotics may also be beneficial in cholesterol lowering [Zhao and Yang 2005] and reduction in Helicobacter pylori infection [Franceschi et al. 2007]. Survival of the bacteria during transit through the stomach and GI tract is essential for achieving these benefits, and, because the probiotic bacteria do not become part of the host’s gut microflora, they must be taken regularly to sustain their beneficial effects.

**Prebiotics**

Prebiotics are indigestible oligosaccharides (small carbohydrate polymers) that enter the large bowel and selectively enhance the growth of certain bacteria within the bowel. Like probiotics, they can favorably alter the microbial balance in the bowel. Key examples include fructose, oligofructose, and inulin, which can be extracted commercially from chicory root, but are also present in other foods, such as artichokes, asparagus, and bananas. Although these substances are not digested in the small intestine, they are fermented by the colonic microflora and selectively stimulate the growth of *Bifidobacteria*. By promoting the growth of beneficial gut bacteria, prebiotics could have similar effects to probiotics. Evidence also suggests that they increase the absorption of certain minerals such as calcium and magnesium [Cashman 2003] and may inhibit pre-cancerous lesions in the colon [Geier, Butler, and Howarth 2006]. The major applications for prebiotics are in dairy products, baked goods and breads, spreads, meat products, salad dressings, and confectionery.

Prebiotics can be mixed with probiotics to produce a symbiotic. The aim is to improve the colonization of the bowel with the probiotic bacteria by use of the prebiotic and/or to stimulate growth of endogenous *Bifidobacteria*. There is some evidence that addition of prebiotics may prolong the colonization by *Bifidobacteria* after consumption of the probiotic is stopped. However, if the effect of the probiotic alone is large, amplification of *Bifidobacterial* colonization by the prebiotic may be difficult to demonstrate.

**Oxidative Stress**

Oxidative stress, which is considered to be attributable to the formation of reactive oxygen species, is believed to be a contributor to aging and many of the diseases associated with aging (e.g., CVD, cancer, cataract, age-related macular degeneration, Parkinson’s disease, Alzheimer’s disease, and osteoarthritis). The body has several defenses against oxidative stress, including antioxidant enzymes and the minerals and trace elements that are involved in the activity of these enzymes, vitamins (e.g., vitamins C and E), and glutathione. If exposure to oxidants is high and the body’s defenses are unable to cope, oxidative stress develops. Antioxidants naturally present in foods (e.g., vitamins C and E, carotenoids, flavonoids, and other polyphenols) are potentially useful candidates for functional ingredients. Plant foods that contain these substances, such as berries (e.g., cranberry, blueberry, goji, and acai),

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mangosteen, pomegranate, tomato, and grape, are increasingly finding application in the functional food industry as potential antioxidants.

Weight Management

During recent decades, the scale of obesity has increased worldwide to epidemic proportions. Obesity develops when energy intake is greater than energy expenditure, the excess energy being stored mainly as fat in the adipose tissue. A number of proposed functional food ingredients have been shown to act pre-absorptively to bind dietary fat in the GI tract or post-absorptively to influence substrate utilization or thermogenesis. These include chitosan, CLA, diglycerides, MCTs, green tea, caffeine, calcium, and capsaicin.

Chitosan

Chitosan is a polysaccharide extracted from chitin, which is a structural component of crustacean shells, crabs, shrimps, and lobsters. Chitosan binds fat molecules as a result of its ionic nature. When taken orally, chitosan has been reported to be able to bind 8–10 times its own weight in fat from food that has been consumed. This prevents fat from being absorbed and the body then has to burn stored fat, which may lead to reductions in body fat and body weight. Human trials with chitosan in obese subjects have produced conflicting results, and any effect of chitosan is likely to be small and of no clinical significance [Jull et al. 2008].

Conjugated Linoleic Acid

CLA is a collective term for a number of naturally occurring isomers of linoleic acid containing conjugated double bonds, both cis and trans. The two most abundant isomers are cis-9, trans-11 CLA and trans-10, cis-12 CLA. CLA is found naturally in food derived from ruminant animals (e.g., cows and sheep) and can also be produced synthetically. CLA is promoted for body weight loss, and there is evidence from animal studies that CLA supplementation could be beneficial in weight management. However, human data are conflicting. CLA appears to affect body composition rather than body weight and might be effective in offsetting lean body mass loss occurring during periods of strict energy control or in elderly people [Silveira et al. 2007]. The trans-10, cis-12 isomer has been suggested to be responsible for these effects and also for the insulin resistance that has been observed in some studies. A mixture of the two isomers, although less potent, may be more suitable for safety reasons, but this has not been proven in human studies.

Diglycerides

Diglycerides are present as minor constituents of various oils. When used in place of triglycerides, which predominate in food fats and oils, diglycerides show some potentially promising effects for weight control. They have a similar energy value
and bioavailability to triglycerides but may not be taken up by the adipose tissue to the same extent as triglycerides because of differences in post-absorptive handling of the diacylglycerol components. In human studies, the magnitude of postprandial triglyceridaemia has been shown to be significantly lower with diglycerides than with triglycerides [Tomonobu, Hase, and Tokimitsu 2006]. Consumption of diglycerides has been associated with greater reduction in body weight and abdominal fat mass compared with triglycerides [Maki et al. 2002]. These effects are thought to be attributable to enhanced postprandial fat oxidation [Saito et al. 2006], which may suppress appetite. However, more studies are required to define the optimal dose, mechanism of action, and magnitude of effect on body weight that can be expected in practice.

Medium Chain Triglycerides

MCTs are triglycerides with fatty acids having a chain length of 6–12 carbon atoms. MCTs occur naturally, particularly in coconut and palm oil. They differ from LCTs in that their fatty acids are absorbed directly into the portal circulation and transported to the liver for rapid oxidation. The exact mechanism by which MCTs may influence energy balance is not clear, although production of ketone bodies may be involved. Postprandial energy expenditure increases in humans after consumption of MCT [St-Onge et al. 2003], and there is some evidence for reduced energy intake when meals are supplemented with MCTs. Data on weight loss are inconsistent, however, with some studies showing weight loss [St-Onge et al. 2008] and body fat loss, whereas others found no effects of MCTs on body weight or body composition [Roynette et al. 2008]. Doses of 10 g/day or more seem to be required for meaningful efficacy, but such high doses limit product quality and palatability and there is a potential for GI adverse effects.

Green Tea

Green tea contains high quantities of catechin polyphenols, such as epicatechin, epicatechin gallate, epigallocatechin, and EGCG, the latter being the most abundant and probably the most pharmacologically active. Green tea also contains catechin. Tea catechins have been shown to inhibit catechol-O- methyltransferase, the enzyme that degrades noradrenaline, whereas caffeine inhibits phosphodiesterase, an enzyme that degrades intracellular cyclic AMP and by antagonizing the inhibitory effect of adenosine on increasing noradrenaline release. Both tea catechins and caffeine are therefore likely to increase the stimulatory effects of noradrenaline on energy and lipid metabolism. In short-term studies, green tea has been shown to stimulate thermogenesis and fat oxidation in some studies [Shixian et al. 2006; Boschmann and Thielecke 2007] but not others [Diepvens et al. 2005]. Long-term studies with green tea constituents have reported decreased body weight and body fat. It is not clear whether discrepancies in the data are attributable to caffeine intake, tea catechins, or both [Westerterp-Plantenga, Lejeune, and Kovacs 2005]. Green tea finds application as a functional ingredient in drinks.
Caffeine

Caffeine has both thermogenic and anorectic properties, but long-term administration of caffeine in doses of up to 600 mg/day has not been associated with reduced weight loss.

Calcium

Dietary calcium plays a pivotal role in the regulation of energy metabolism. High calcium diets reduce adipose tissue accretion and weight gain during periods of overconsumption and increase fat breakdown to preserve thermogenesis during energy restriction, thereby accelerating weight loss [Zemel 2002]. A review analyzing data from six observational studies and three controlled trials has shown that high calcium intakes are associated with lower weight gain at mid-life [Heaney, Davies, and Barger-Lux 2002]. However, these effects are difficult to separate from other dietary and lifestyle factors, most notably the consumption of dairy products that are low in energy density and high in protein.

Capsaicin

Capsaicin and other pungent spices have attracted attention as functional ingredients because of their enhancement of fat oxidation and thermogenesis. However, long-term data in humans are lacking, and the use of capsaicin as a functional ingredient may be limited by its pungency and burning effect in the mouth and stomach.

Diabetes Mellitus

Overweight and lack of physical activity have been consistently associated with increased risk of type 2 diabetes. However, dietary composition also appears to be important, and the diet for the management of type 2 diabetes is not significantly different from that recommended for diabetes prevention. Available evidence supports the use of whole-grain foods, vegetables, fruits, foods low in saturated fat, and starchy foods with a low glycemic index. Given that compliance with dietary recommendations in diabetes is often poor, functional foods may be valuable in both treatment and prevention. Low glycemic index starchy foods are of particular interest because of their potential beneficial effects on glucose metabolism and insulin sensitivity. Oral amino acids in the form of snacks have also been studied to positive benefits in blood glucose control and insulin sensitivity in a recent trial in patients with type 2 diabetes [Solerte et al. 2008]. Spices such as cinnamon, coriander, garlic, and turmeric may also be beneficial antidiabetic food adjuncts [Srinivasan 2005].

Numerous studies suggest that chromium, particularly NBC or chromium-nicotinate, may be effective in attenuating insulin resistance and lowering plasma cholesterol levels. Genetics appear to have an influence on these effects, and nutrigenomic studies may help to shed light on the individuals who could benefit from additional chromium [Lau et al. 2008].
Cognitive and Mental Health

A number of functional food ingredients could benefit cognitive and mental function. These include ingredients that are associated with immediate effects such as caffeine, guarana, and ginseng, which can lead to improvement in measures of cognitive performance (e.g., reaction time, attention, vigilance, and psychomotor performance). Carbohydrates exert beneficial effects on various aspects of mental performance, such as faster information processing, better word recall, and improvements in decision time and working memory, but high carbohydrate meals will eventually produce drowsiness and sleepiness whereas the amino acid tryptophan promotes drowsiness and fatigue and reduces the time to sleep.

Other ingredients are associated with longer-term effects, such as reduction in depression, changes in memory, and mental performance in aging with the possibility of reducing the risk of dementia, including Alzheimer’s disease. Omega-3 fatty acids, SAMe, and folic acid have attracted attention as potential functional ingredients for depression, whereas Ginkgo biloba and omega-3 fatty acids represent potential functional ingredients for the prevention of age-related mental changes.

Joint Health

Osteoarthritis is one of the most prevalent and debilitating chronic conditions affecting older people. Current recommendations for management include nonpharmacological measures such as weight loss and increased physical activity and pharmacological interventions (e.g., NSAIDs). Serious adverse effects are associated with the use of NSAIDs, which creates a need for safe and alternative therapies. In addition, the absence of any cure for osteoarthritis makes prevention important. Nutraceuticals such as glucosamine and chondroitin are used as food supplements but are starting to find application as functional ingredients in foods. Evidence is also emerging for collagen hydrolysate, methylsulfonylmethane, SAMe, and soybean unsaponifiables, all of which could be used as functional ingredients in foods [Ameye and Chee 2006; Bello and Oesser 2006; Frech and Clegg 2007; Clark et al. 2008].

Specific functional functions with their key ingredients and claimed health-promoting benefits are shown in Table 19.1.

DIETETIC FOODS

Another type of “dietary food” is the so-called “dietetic food.” In Europe, these are defined as foodstuffs intended to satisfy the nutritional requirements of specific groups of the population and are intended for individuals with a specific disease or condition. In contrast to functional foods, they are legally defined. They are also marketed directly to health professionals, whereas functional foods are marketed to consumers. Examples of dietetic foods include the following:
Table 19.1  Examples of Functional Foods and Drinks on the U.K. Market in 2008

<table>
<thead>
<tr>
<th>Product</th>
<th>Examples of Claims on Product Packaging and/or Product Website</th>
<th>Key Ingredient Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Products fortified with vitamins and minerals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fortified breakfast cereals (e.g., Kellogg's, Nestle, Weetabix, grocery stores' own brands)</td>
<td>&quot;With 6 additional vitamins to keep you fighting fit all day long. Vitamin C to help iron absorption; vitamins B1, B2 and B6 to help turn food into energy; provitamin A to help support healthy skin and eyes; vitamin E, as an antioxidant, to help protect your cells.&quot;</td>
<td>Range of vitamins and minerals</td>
</tr>
<tr>
<td>Tropicana Essentials Multivitamins</td>
<td></td>
<td>Range of vitamins and minerals</td>
</tr>
<tr>
<td>Conventional food products with no added nutrients</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optivita (Kellogg's) cereals and cereal bars</td>
<td>&quot;Oats as part of a balanced diet low in saturated fat and healthy active lifestyle can help reduce blood cholesterol. Optivita contains 0.8g of oat beta glucan per 30g serving.&quot;</td>
<td>Beta-glucan</td>
</tr>
<tr>
<td>Quaker Oats</td>
<td>&quot;Oats contain a soluble fibre which soaks up cholesterol. Reducing your cholesterol can help maintain a healthy heart.&quot;</td>
<td>Beta-glucan</td>
</tr>
<tr>
<td>Shredded Wheat (Nestle)</td>
<td>&quot;100 per cent whole grain wheat. Whole grain foods contain a combination of protein, fibre, vitamins, minerals, antioxidants and carbohydrates. Together these help keep your heart healthy and help maintain a healthy body.&quot;</td>
<td>Whole-grain wheat</td>
</tr>
<tr>
<td>Tropicana Orange Juice</td>
<td>&quot;Just 150ml of Tropicana Pure Premium equals one of your 5 daily portions of fruit and vegetables as recommended by health and medical experts. But a 250ml glass of delicious Tropicana Orange Juice contains a full day’s supply of vitamin C, provides a good source of folic acid (33%RDA), is naturally sodium and fat free, provides a tasty way to promote healthy blood pressure.&quot;</td>
<td>Vitamin C naturally present in the orange juice</td>
</tr>
<tr>
<td>Products with added calcium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tropicana Essentials Calcium</td>
<td>Calcium is renowned for its vital role in keeping your bones strong and healthy. Tropicana Essentials Calcium contains the same level of calcium as milk—meaning it's a great source of this essential nutrient for anyone who is lactose-intolerant, or doesn't like milk.</td>
<td>Calcium</td>
</tr>
</tbody>
</table>
### Products with added fibre

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropicana Essentials Fibre</td>
<td>Extra fibre to keep your digestive system regular</td>
<td></td>
</tr>
<tr>
<td><strong>Products with added omega-3 fatty acids</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brainstorm iQ3 cereal bars</td>
<td>“with Omega-3 and Omega-6, which may help concentration and brain and eye function”</td>
<td></td>
</tr>
<tr>
<td>Columbus eggs</td>
<td>“Columbus eggs contain twice as much polyunsaturated fatty acids as standard eggs”</td>
<td>850 mg of long-chain omega-3 fatty acids/egg</td>
</tr>
<tr>
<td>Flora Omega 3 Plus spread</td>
<td>“An average serving will provide you with a third of your recommended daily intake of fish sourced Omega 3.”</td>
<td>One serving (2 x 10 g) = 600 mg of plant omega-3 and 135 mg of fish omega-3</td>
</tr>
<tr>
<td>Flora Omega 3 Probiotic Plus Mini Drink</td>
<td>“Packed full of Omega 3—which helps to maintain heart health—and friendly bacteria, making it great for your digestive system.”</td>
<td>EPA/DHA, 80 mg per drink</td>
</tr>
<tr>
<td>St. Ivel Fresh Milk with Omega 3</td>
<td>“Contains at least 20x more long chain omega 3 (EPA and DHA) than any other standard whole or semi-skimmed milk.” St Ivel Fresh Milk with Omega 3 contains the most important long chain Omega 3s derived from fish oils. These are the most effective and their health benefits are widely acknowledged.</td>
<td>113 mg of long-chain omega-3 per 250 ml serving</td>
</tr>
</tbody>
</table>

### Products with added phytosterols

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benecol (spreads, dairy free drinks, yogurt drinks, yogurts, cream cheese)</td>
<td>“Helps block the uptake of cholesterol in the gut. Therefore, with Benecol less cholesterol enters the blood stream.”</td>
<td>Plant stanols</td>
</tr>
<tr>
<td>Flora Pro-Activ (spreads, mini drinks, yogurts, semi-skimmed milk drinks)</td>
<td>“Plant sterols can lower LDL by 10–15% in just three weeks, when moving to a healthy diet and lifestyle.”</td>
<td>Plant sterols</td>
</tr>
<tr>
<td>Minicol cheese</td>
<td>Extensive clinical trials, undertaken in a U.K. research Institute, have demonstrated that the newly developed product reduces overall cholesterol levels by an average of 5.7%, bad (LDL) cholesterol levels falling by 17%.</td>
<td>Plant sterols</td>
</tr>
</tbody>
</table>

(Continued)
<table>
<thead>
<tr>
<th>Product</th>
<th>Examples of Claims on Product Packaging and/or Product Website</th>
<th>Key Ingredient Content</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Products containing prebiotics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Danone Actimel yogurt drink</td>
<td>“More resistant to the digestive process than some other cultures (which means more of the bacteria make it into your intestine) L. casei Imunitass helps support your body’s defences by topping up the levels of good bacteria found in your gut.”</td>
<td>L. casei immunitas</td>
</tr>
<tr>
<td>Danone Activia yogurt</td>
<td>“Activia helps keep your digestive system ticking away nicely by helping to improve slower digestive transit. A slower transit may make you occasionally feel bloated which can make you feel uncomfortable in yourself. Activia is the only yogurt in the UK that is scientifically proven to help improve slower digestive transit”</td>
<td>Bifidus Actiregularis</td>
</tr>
<tr>
<td>Muller Vitality (yogurts and yogurt drinks)</td>
<td>“Each bottle contains pre and probiotics to help maintain a healthy digestive system. Keeps your tummy working like clockwork.”</td>
<td></td>
</tr>
<tr>
<td>Yakult fermented drink</td>
<td>“Self defence for your gut”</td>
<td>Live probiotic strain of Lactobacillus casei Shirota</td>
</tr>
<tr>
<td><strong>Products with added prebiotics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muller Vitality Yogurts and Yogurt Drinks</td>
<td>“Each bottle contains pre and probiotics to help maintain a healthy digestive system. Keeps your tummy working like clockwork.”</td>
<td></td>
</tr>
<tr>
<td>Warburton’s Healthy Inside Bread</td>
<td>Inulin “works by feeding or stimulating your own good bacteria to grow and multiply, thus increasing the amount of good bacteria in your body.”</td>
<td>Inulin</td>
</tr>
<tr>
<td><strong>Products with added peptides</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flora Pro-Activ Blood Pressure Mini Drink</td>
<td>“Control blood pressure”</td>
<td>Ameal peptide containing 6.6 mg of dairy peptides</td>
</tr>
</tbody>
</table>

Table 19.1 (Continued)
**Products containing soya**

- **Alpro soya products** (alternatives to milk, yogurt and cream), desserts, tofu
  - "Can help to lower your cholesterol (25g of soya protein per day as part of a diet which is low in saturated fat has been proven to lower your cholesterol levels)."
  - Soya

- **Burgen Soya and Linseed Bread**
  - "Soya and linseeds are good sources of plant oestrogens which may be beneficial for women's health."
  - Soya

- **So Good soya milk**
  - "All So Good products contribute to developing these 5 important health benefits: healthy heart, strong bones, lowers LDL (bad) cholesterol, low GI, protective antioxidants."
  - Soya

**Products promoted for antioxidant content**

- **Devaux-Acticoa chocolate**
  - "Acticoa dark chocolate contains 2.33 times the antioxidants you’ll find in standard dark chocolate; 9g a day delivers the RDA of antioxidants."
  - Website states that Acticoa cocoa drink (2.5% cocoa powder) per serving contains 540 mg of total polyphenol and 342 mg of total flavanol (for an equivalent standard cocoa drink, the figures stated are 210 and 188 mg, respectively)

- **Diet Coke Plus Antioxidant**
  - "Antioxidant"
  - Green tea powder, vitamin C

- **Innocent Superfood Smoothies (various blends)**
  - Contain various blends of fruits for which antioxidant claims are made, e.g. "goji berries, full of antioxidants and the richest source of beta-carotene of all known foods on earth"; *pomegranates, blueberries and acai, all of which contain high levels of antioxidants."

- **Lipton Green Tea (soft drink)**
  - "Source of green tea antioxidants"
  - Green tea extracts, 10.8%

- **Ocean Spray (various juice drinks and juices containing cranberry with and without other fruits such as blueberry, blackcurrant, raspberry, mango)**
  - "Rich in vitamin C and antioxidants."
  - Vitamin C, 75 mg/250 ml serving

100ml of Ocean Spray Cranberry and Pomegranate will typically contain 40mg proanthocyanidins.
<table>
<thead>
<tr>
<th>Product</th>
<th>Examples of Claims on Product Packaging and/or Product Website</th>
<th>Key Ingredient Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>PomWonderful Pomegranate Juice</td>
<td>&quot;There are antioxidants, and then there are antioxidants. Only POM Wonderful 11% Pomegranate Juice is backed by over £10million of initial scientific research that’s shown encouraging results for prostate and cardiovascular health. And every sip helps guard your body against free radicals.&quot;</td>
<td>Antioxidant activity quoted as 6.1 mM polyphenols</td>
</tr>
<tr>
<td>Pomegreat (various drinks, e.g., Pomegreat Original; Blueberry; Raspberry; Pomegreat 100; Pomegreat 100 Blueberry; Pomegreat Acai)</td>
<td>A 250 ml glass of Pomegreat provides half an adult’s RDA of antioxidant vitamins A, C and E. “Bursting with antioxidants, they (pomegranates) also have cholesterol lowering properties”; “Packed with antioxidant vitamins” “Pomegranates are bursting with antioxidants”; “Fantastic source of antioxidants, which naturally defend and protect your body against free radicals”; “Acai berries are brimming with antioxidants”;</td>
<td>Vitamin C, 30 mg/250 ml serving; vitamin E, 5 mg/250 ml serving</td>
</tr>
<tr>
<td>Rubicon (pomegranate, blueberry and cranberry exotic blend)</td>
<td>“Pomegranates, blueberries and cranberries are known as superfoods and are crammed full of antioxidants.”</td>
<td>Vitamin C, 60 mg/200 ml serving</td>
</tr>
<tr>
<td>Tropicana (blueberry blend; pomegranate blend) juices</td>
<td>“Rich in antioxidants”</td>
<td></td>
</tr>
<tr>
<td>Welch’s Purple Grape Juice, Purple Grape and Raspberry Blend, Purple Grape and Strawberry Blend</td>
<td>“Natural antioxidant power”; “Packed full of antioxidant power”; “Welch’s Concord Purple Grape has more naturally occurring antioxidant power than many other popular fruit juices”; “The Concord Purple Grape is higher in antioxidants than more common red and white grapes.”</td>
<td>Antioxidant activity measured using ORAC; absolute values not quoted on the label</td>
</tr>
</tbody>
</table>
Dietary Foods

- Foods for infants and young children, including infant formulas and follow-on formulas, processed cereal-based foods, and baby foods (weaning foods)
- Foods intended for use in energy-restricted diets for weight reduction
- Foods for sports people and athletes
- Foods for special medical purposes (e.g., enteral/tube feeds, gluten-free foods for celiac disease)

Future Developments

The trend for increasing numbers of functional ingredients and functional foods has increased during recent years. Whether and how much this will continue is at present unclear. Factors that will encourage future development of dietary foods include the increasing global burden of obesity and the health conditions associated with it (e.g., CVD and diabetes) and an increasingly older population and the health problems common in that group (e.g., decline in bone mass, joint function, vision, and cognitive function). Pressures of cost containment for health systems and an emphasis on prevention, well-being, and self care could also help to drive this market forward.

Rapid developments in nutritional science and food technology will likely create opportunities for new food products. An understanding of components beyond traditional nutrients (e.g., phytochemicals) will likely lead to the development of new active ingredients. Furthermore, knowledge of mechanisms and development of valid biomarkers should help in the development of more target and disease-specific foods. New formulations, such as nutritional patches and sprays, will be introduced to deliver functional ingredients. New technologies with validated biomarkers could enable consumers to measure their own nutritional status and to assess the effects of functional foods on their health.

Functional foods of the future are likely to be targeted at specific subgroups of the population for very specific health benefits. To this end, the influence of genes on metabolic processes, the influence of foods on genetic expression, and individual susceptibility to diet-related disease will help in the production of specific functional foods for specific population groups.

However, future challenges for functional foods lie in the possibility of a return to “fundamental eating patterns” and increasing consumer skepticism of manufactured food products carrying health claims. Regulation, both nationally and internationally, particularly for product claims and labeling, is also likely to increase. Restrictions on genetically modified ingredients will also shape the future of functional foods. Education will be of paramount importance if consumers and the professionals who advise them are to understand the value of these foods and consume them.

References


