Chemical Composition of Bakery Products

9

Cristina M. Rosell and Raquel Garzon

Contents

Abstract

Cereals have always occupied a preferential place in the food pyramid that gathers dietary guidelines. Despite society lifestyle changes, cereal-based goods are still the main players in the human diet, although their worldwide contribution to dietary patterns is different. Regarding cereals' role in the daily diet, three different categories could be considered worldwide: (i) cereals as staple/basis food, (ii) cereal-based goods as carriers of micronutrients or fortification, and (iii) cereal-based foods tailored for specific needs. Bread is the main bakery consumed product worldwide, although the concept of bread comprised thousands of different products regarding their processing, shapes, composition, and so on. Although with far less consumption, other bakery products include

C.M. Rosell (✉) • R. Garzon
Department of Food Science, Institute of Agrochemistry and Food Technology, Spanish Research Council, IATA-CSIC, Paterna, Valencia, Spain
e-mail: crosell@iata.csic.es; ragarllo@gmail.com

P.C.K. Cheung, B.M. Mehta (eds.), *Handbook of Food Chemistry*,
DOI 10.1007/978-3-642-36605-5_22

cookies, cakes and muffins, croissants, and pastries. An overview about the chemical composition of cereals and cereals products, as well as their role in human nutrition and health, is presented.

Introduction

Cereals constitute the raw commodities of the bakery products; because of that, a special consideration is given to the chemical composition of cereals and the impact of processing on that composition. Cereals are the edible seeds of the grass family, *Gramineae*. The global importance of cereal crops to the human diet has been in parallel to the written history of man and agriculture. Bakery products are mainly fermented cereal-based products subjected to a high-temperature process for increasing their organoleptic properties and shelf life. Cereals are the most important group of food crops produced in the world. In the last 50 years, cereal production has experienced a progressive linear increase, responding to the greater demand owing to population increase. Despite changes in lifestyles and cereal utilization, half of the cereal production is destined to human food (Fig. 1); only a slight modification has occurred in cereal utilization; in the 1960s, 51 % of the cereal production was utilized for human consumption, whereas in the twenty-first century, 52 % of the production is dedicated to food and food manufacture. Even better picture of the cereal contribution to the human diet could be obtained from the yearly consumption per capita that reached the maximum point, 150 kg/person year, in the 1990s, but it decreased to 147 kg/person year during the last two decades, owing to the shift to animal-based foods when income increases.

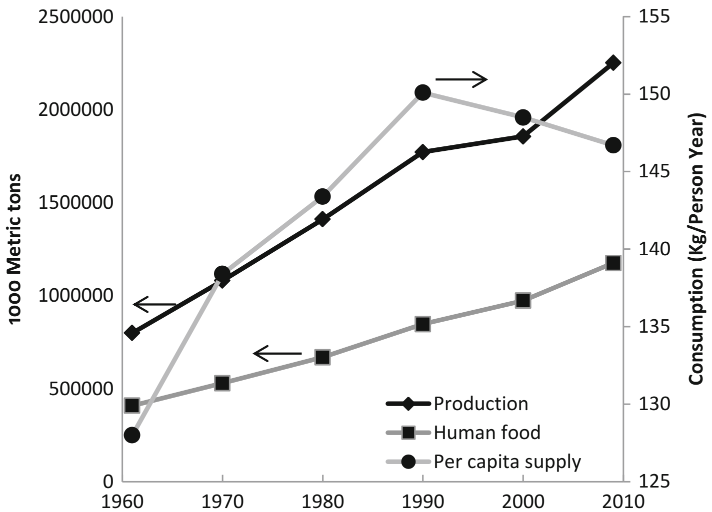

Fig. 1 Cereals as human food over the last 50 years

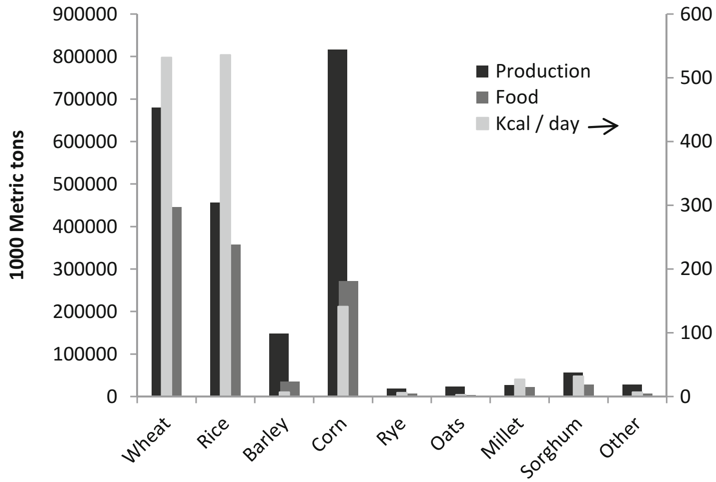

Fig. 2 Cereal production and contribution to the daily food intake in 2009

Cereal-based products are really ancient products that comprise a diversity of foods mainly obtained from wheat, rice, corn, millet, teff, and other minor cereals. Major cereal crops produced worldwide include wheat, rice, corn, and barley. Corn (or maize) represents the greatest (36 %) cereal crop for agriculture, but it has relatively less importance than wheat and rice because only one-third of its production is destined to human consumption, in comparison with the 66 % and 79 % of the wheat and rice used as human foods, respectively (Fig. 2). Some other minor cereals include sorghum, millet, oat, rye, and some pseudocereals as quinoa and amaranth.

Cereals still remain on the basis of the human nutrition because they lead to nutrient-dense baked goods. However, the weight of the cereals as an individual source of nutrition varies with region, depending upon the importance of a grain to the development of that culture. Cereal grains, such as wheat, rice, corn, barley, sorghum, millet, and oats, account for most of the food consumed by humans. Rice is more important to the development of Eastern cultures, where its cultivation is concentrated, and wheat is more significant to Western ones. Globally, wheat nourishes more people than any other grain, and it is a major part of the diet for one-third of all people. The majority of wheat is milled into flour and it is the basis of more foods than any other grain.

Cereal crops are energy dense, providing about 10–20 times more energy than most succulent fruits and vegetables. Nutritionally, they are important sources of dietary protein, carbohydrates, the B complex of vitamins, vitamin E, iron, trace minerals, and fiber. It has been estimated that global cereal consumption directly provides about 32 g of protein per person and day and 5.9 of fat per person and day, being the highest contribution in the developing countries (Table 1).

However, cereals are mainly consumed after milling or processing which significantly change their composition, due to removal of the outer parts, and consequently the composition of the derived baked products.

Table 1 Contribution of cereals to human nutrition in different world regions (Data source: FAOSTAT 2014)

	Food/capita/year (kg)	Kcal/capita/day	Proteins/capita/day (g)	Fat/capita/day (g)
World		1,292	32.0	5.9
Africa	151	1,283	34.0	8.4
Northern America	109	831	24.4	3.6
Central America	153	1,283	32.9	11.5
South America	118	972	23.3	3.1
Asia	155	1,421	33.5	5.9
Europe	131	1,002	29.9	4.0
Oceania	98	792	22.9	3.1

Apart from the nutritional contribution, cereals have important nutraceutical and health benefits that go beyond the provision of nutrients. The consumption of cereal based foods products produces feelings of satiety; and their regular consumption in the main meals appears to be key drivers of healthier dietary patterns (Aisbitt et al. 2008). Nevertheless, consumption of cereal-based foodstuff has been attached to several misconceptions: first the association of cereals, mainly wheat-based goods, with food intolerance or allergy and second the link between cereals and fattening effect (Aisbitt et al. 2008). Therefore, unless following the advice from a registered dietitian or other health professional, consumers must be skeptical to all those currents and do not eliminate unnecessarily this whole food group because they provide a range of macro- and micronutrients and fiber. Dietary fiber, beta-glucan, resistant starch, carotenoids, phenolics, tocotrienols, and tocopherols have been related to disease prevention like cardiovascular diseases and strokes, hypertension, metabolic syndrome, type 2 diabetes mellitus, obesity, as well as different forms of cancer (Yu et al. 2012).

Cereals have a variety of uses as food. Owing to their protein functionality, only two cereals, wheat and rye, are suited to the preparation of leavened bread. Because of that, this chapter will be mainly referred to baked goods derived from those crops, although mention will be made to corn due to its use for producing tortillas, which are extensively consumed in Mexico and their commercialization has been extended around the world.

Worldwide Consumption of Bakery Products

The almost ubiquitous consumption of cereals all over the world confers cereals a prominent position in international nutrition. Cereal-based products account great part of our daily diet through the consumption of bread, breakfast cereals, cookies, snacks, cereal bars, cakes, and so on. The total consumption of bread, viennoiserie, and patisserie was estimated as nearly 39 million tons in the 27 EU countries.

Worldwide bread consumption accounts for one of the largest consumed foodstuff, with an average consumption ranging from 41 to 303 kg/year per capita, which becomes an essential part of the human diet, enjoyed at various times of the day. Bread, through the different forms, is the most widely consumed food worldwide. It is handy and very convenient for the on-the-go consumers, available in any place and during all year around, affordable, and from nutritional point of view a source of energy in the form of starch, besides the supply of dietary fiber and a range of vitamins and minerals.

Bread has changed in many ways since our ancestors, going from a grainy flatbread to an aerated texture (Fig. 3). Bread is the product of fermenting and baking a mixture of whole wheat or refined flour, water, salt, and yeast or baking powder, as the basic ingredients. With the years, innovation has been focused on industrial processing (Rosell 2009), and, more recently, trends drive to obtain nutritious bread in response to the health concerns of the consumers.

A study for the European Commission in 2010 found that the European bread market was around 32 million tons in the 27 EU countries and the market share of the industrial bakers versus the craft bakers was approximately 50/50 although great differences were encountered among countries. Bread consumption patterns differ widely within the EU but most countries have an average consumption of 50 kg of bread per person per year.

Sliced pan bread is greatly extended in the USA, but Europe's consumers prefer crispy breads with crusty surface like French baguette. The opposite sensory characteristics could be found in the steamed bread that is consumed in Asian countries. In India, flatbread called chapatti is consumed in the main meals, whereas flatbread in Mexico is made of corn and it is named tortilla. In Finland and Germany, a very dark rye bread, made of 100 % rye flour, is the most common bread. In Venezuela, the arepas are considered a staple part of the diet, and they are eaten for breakfast, as a snack, or together with a meal. In Brazil, pão de queijo, small, round, cheese-stuffed bread balls, are traditionally served for breakfast. It seems that the term bread comprises thousands of different types of breads around the world and even there is a big diversity within each country.

Bread consumption patterns differ widely around the world. For instance, within the EU, the average consumption is 106 g of bread per person per day, in contrast with the 40 g per person per day of fine bakery wares and around 10 g per person per day of breakfast cereals (EFSA Comprehensive European Food Consumption Database, published in March 2011). Bread consumption in Western Europe is stable although it varies greatly between countries. Germans and Austrians show the highest consumption of bread at around 80 kg/year, although the greatest annual consumption registered in the Guinness World Records belongs to Turkey in 2000 with 199.6 kg per person followed by Serbia and Montenegro with 135 kg and Bulgaria with 133.1 kg. In opposition, the UK and Ireland have an annual consumption of less than 50 kg/year.

Bread is also a staple food in the diet of American consumers, principally for adult men and women 55 years and older, households with low annual incomes,

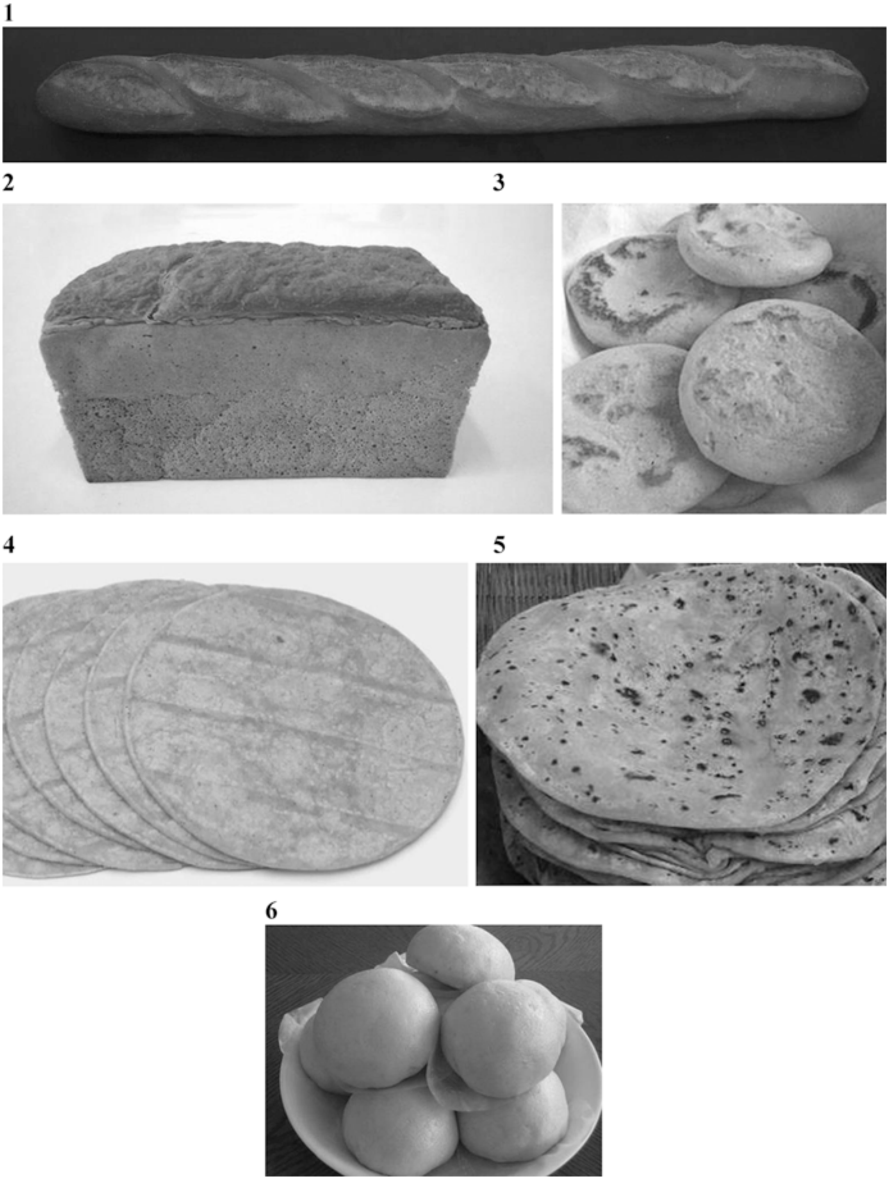

Fig. 3 Bread types worldwide. 1. White bread; 2. Pan bread; 3. Pita bread; 4. Tortilla; 5. Chapatti; 6. Chinese steamed bread

households led by a homemaker with some high school education, single and married active seniors, and Black/non-Hispanic ethnic groups.

Lately, the driving force for increasing bread consumption is the innovation in ethnic breads and the production of greater varieties of whole wheat breads with oats, bran, seeds, etc. that are more nutritious products to attract health-conscious consumers (Lambert et al. 2009). There is also a growing trend for increased production of morning goods and specialty breads with lots of opportunities for innovation. Nevertheless, some popular diets, such as the Paleo and gluten-free diets, have limited the consumption of wheat breads. Changes in demand for bread have induced a growing demand for low-carbohydrate foods, whole grains, and gluten-free products. Companies have successfully attracted these health-conscious consumers by introducing products such as low-calorie "sandwich thins" and gluten-free products. This shift in consumer preferences has been attributed to more sophisticated consumer tastes and their desire for healthier and more nutritious food, in line with lowering sodium, besides the looking for more exotic or ethnic varieties and new formats, like thinner slices.

Chemical Composition of Cereals and Changes Associated to Milling and Proofing

The chemical composition of bakery products is mainly dependent on the commodity used for their production; because of that, the chemical composition of the different cereals that are used as raw materials in bakeries is considered crucial. All cereal grains have a fairly similar structure and nutritive value although the shape and size of the seed may be different (McKevith 2004). Cereal grains are formed of bran or the outer layers, endosperm and germ. Cereals are the major providers of food carbohydrates, representing about 50 % of all the carbohydrates consumed worldwide.

Cereals are quite similar in gross composition, being low in protein and high in carbohydrates. Regarding composition, cereals consist of 12–14 % water, 55–75 % carbohydrates, 1.5–6 % lipids, and 7–12 % protein; mineral composition varies from 1.4 % to 2.5 % and the fiber content ranges from 0.8 % to 4.1 %. Barley, sorghum, rye, and oat proteins have lower digestibility (77–88 %) than those of rice, corn, and wheat (95–100 %). The biological value and net protein utilization of cereal proteins are relatively low due to deficiencies in essential amino acids and low protein availability. Cereals provide B-group vitamins and minerals like phosphorous, potassium, magnesium, calcium, and traces of iron. Cereals are low in saturated fat but they are a source of polyunsaturated fats, including omega-3 linolenic acid, and also cholesterol-free.

Whole-grain intakes and specially cereal fiber have been repeatedly associated in the epidemiological literature with reduced mortality and risk of chronic disease including obesity, cardiovascular diseases, and type 2 diabetes (Smith and Tucker 2011; Borneo and León 2012).

Nevertheless, cereals are not consumed as grains. They undergo milling to obtain flour that has particular functionality for creating and developing an infinity of breads that differ in shapes, structure, and sensory characteristics. The chemical constituents of cereals are not evenly distributed in the grain. Bran that represents 7 % of the grain contains the majority of the grain fiber, essentially cellulose and pentosans, it is a source of B vitamins and phytochemicals, and 40–70 % of the minerals are concentrated in this outer layer. The endosperm, the main part of the grain (80–85 % of the grain), is composed mainly of starch, it has lower protein and lipid content than the germ and the bran, and it is poor in vitamins and minerals. The germ, the small inner core, represents around 21 % of the grain, and it is rich in B-group vitamins, proteins, minerals like potassium and phosphorous, healthful unsaturated fats, antioxidants, and phytochemicals. Cereals are rich in glutamic acid, proline, leucine, and aspartic acid and are deficient in lysine. The amino acid content is mainly concentrated in the germ.

Milling provokes the reduction in nutrients and micronutrients that are mainly concentrated in the outer layers and germ. In the conversion of cereal grains to white flour, bran and germ are removed and with them the majority of the fibrous layers of the grain, B vitamins, phytochemicals, 50–80 % of the grain minerals, and lipids. Globally, twenty or more ingredients, such as thiamine, riboflavin, niacin, pyridoxine, folate, pantothenate, biotin, vitamin E, calcium, copper, iron, potassium, magnesium, manganese, phosphorus, zinc, chromium, fluorine, molybdenum, and selenium, are lost to the extent of 50–90 % during the milling process (Rosell 2008). Conversely, white flour contains mostly starch, protein, and low content of fat, vitamins, and minerals.

The consumption of processed or refined products may reduce the health benefits of the original food. In wheat-based processed foods, the removal of external layers and germ is parallel to the reduction in nonessential phytochemicals such as carotenoids, polyphenols, phytosterols/stanols, and dietary fibers. In consequence, those refined products have lost the potential ability to reduce the risk of major chronic diseases of humans, such as cancer, cardiovascular diseases, and Parkinson's disease.

Wheat is the most commonly used cereal for producing bakery goods. Wheat and wheat-based products have been the basis of the human diet for many centuries, so any process that leads to a decrease in the nutritional value of these products results in a reduction in the daily supply of fiber, vitamins, and minerals. The increasing awareness of the potential benefits of high-fiber diets has prompted a growing interest in the consumption of whole-grain breads or bran breads. The complex carbohydrates, mainly starch, are the major components of wheat (61–65 %), but it is also an excellent source of dietary fiber (9–12 %), composed mainly of cellulose, complex xylans, lignin, and ß-glucans, which are located in the outer layers of the grain. The protein content of wheat is one of the highest in cereals; it ranges between 10 % and 15 %. The predominant amino acids are glutamic acid, proline, leucine, and aspartic acid and are mainly concentrated in the germ. The fat content is very low (1.7–2.0 %) and is mainly polyunsaturated with an absence of cholesterol. With respect to the micronutrient composition, wheat is also a source of B vitamins, namely, thiamine (B_1), riboflavin (B_2), and niacin (B_6), and minerals. Important amounts of calcium, phosphorus, iron, sodium, magnesium, and potassium are found in the aleurone layer of wheat.

Cereals and other plant foods may contain significant amounts of toxic or antinutritional substances. Most cereals contain appreciable amounts of phytates and enzyme inhibitors, and some cereals like sorghum and millet contain large amounts of polyphenols and tannins. Some of these substances reduce the nutritional value of foods by interfering with the mineral bioavailability and digestibility of proteins and carbohydrates. Special consideration must be paid to phosphorus, since it is forming the complex phytic acid or myo-inositol hexaphosphate, which it is not readily available and is considered an antinutritional compound because of its adverse effects on the bioavailability of minerals. Other health-promoting compounds mainly concentrated in the germ and bran are the phytochemicals. These phytochemicals include lignans, a phytoestrogen that can lower the risk of coronary heart disease and may protect against hormonally linked diseases such as breast and prostate cancers.

Other phytochemicals include saponins, phytosterols, squalene, oryzanol, and tocotrienols, which lower blood cholesterol, and some phenolic compounds that have antioxidant effects.

The consumption of wheat is recommended due to its excellent nutritional profile, consisting of: (i) complex carbohydrates; (ii) dietary fiber; (iii) low fat content (without containing cholesterol); (iv) minerals, especially calcium, phosphorus, iron, and potassium; and (v) B vitamins.

Milling Impact on the Nutritional Composition of Cereals

Whole wheat flour contains all the constituents and nutrients from the grain; thus, no losses are produced when milling whole grains. Nevertheless, during the twentieth century, consumers move their preferences to white bakery products, which were a sign of high quality; in consequence, refining became a common practice for millers. Milling removes the external layers and germ of the grains and the extraction rate is indicative of the milling yield. Higher extraction rate means high recovery of flour from the initial grain; thus, more nutrients are recovered in the resulting flour. However, for obtaining white flour, extraction rates must be lowered to 65–70 %, increasing the starch concentration in the flour and with the subsequent losses of the rest of constituents. Wheat processing like milling can result in a significant change in the nutritional value of the ultimate wheat products. The nutrients concentrated in the bran layers and germ will be removed during the traditional or conventional milling. The most affected compound during conventional milling is the crude fiber followed by the ash (minerals) and vitamins, having a detrimental effect on the nutritional value. Without the bran and germ, about 25 % of the grain proteins are lost, along with 66 % of fiber, 92 % of selenium, 62 % of folate, and up to 99.8 % of phytochemicals (Rosell 2012). Some fibers, vitamins, and minerals may be added back into refined cereal products, which compensates for losses due to refining, but it is impossible to recover the phytochemicals lost in the processing. Other alternatives to improve the nutritive value of cereals include traditional genetic selection, genetic engineering, nutrient and micronutrient fortification, complementation with other proteins (particularly legumes), milling modifications, heating, and germination.

Agronomic fortification has been a very useful alternative for increasing the level of micronutrients in the edible parts of the plants, which is known as biofortification. Biofortification focuses on the agricultural modifications as a public health intervention, which could have a direct impact on the diet of the low-income consumers, who are often at highest risk for micronutrient deficiencies. HarvestPlus is a Challenge Program of the Consultative Group on International Agricultural Research (CGIAR) in which the objective is to design, produce, test, and disseminate staple food crops that are biofortified with iron, zinc, and provitamin A. Under this program, a steady progress in breeding for biofortified crops has been achieved, with satisfactory results regarding levels of zinc and provitamin A carotenoids and iron in several staple food crops, including maize, rice, wheat, pearl millet, potatoes, and bananas or plantains.

Biofortification can be accomplished by either mineral fertilization or plant breeding. Biofortification by mineral fertilization is a common practice in some countries that applied selenium-containing fertilizers as a short-term solution for improving the selenium content of wheat. Selenium is an essential micronutrient for humans and may reduce the risk of degenerative diseases including cancer, but it is deficient in at least a billion people worldwide. Wheat is a major source of dietary selenium in humans. The intake of selenium through the baked goods obtained from agronomically biofortified wheat increases the plasma selenium concentration but without modifying substantially the selected biomarkers of degenerative disease risk and health status. Biofortification through plant breeding consists of the development of micronutrient-enhanced crop varieties through conventional breeding. Nevertheless, the implementation of this type of biofortification requires the identification of genetic resources, to determine the interaction of genotype and environment, to define the desired level of micronutrient increase, and finally to assess the cost-effectiveness. So far, it seems a sustainable and cost-effective approach for reaching biofortification in zinc and iron. Past efforts have focused on increasing crop yields, but today the enhancement of the nutritional quality of the crops has become an urgent task because about half of the world population suffers from malnutrition with respect to iron, zinc, and selenium.

Another agronomical approach for enhancing the nutritional value of wheat flour is the expression of a heat-stable phytase, which is more resistant to baking or processing temperatures and can degrade phytate more efficiently. Phytase is an esterase that catalyzes the stepwise hydrolysis of phytates to phosphate and inositol via penta- to monophosphates, thus progressively reducing the ability of phytates to complex with minerals (binding with minerals renders phytates nonabsorbable in the intestines). Animal feeding experiments confirmed a significant improvement in zinc bioavailability from transgenic wheat containing a heat-stable phytase.

Germination or sprouting has been traditionally applied at a household level to improve the nutritional, functional, and sensory properties of grains such as pulses and cereals. Pulses are a particularly rich source of vegetable proteins, dietary fibers, vitamins, and minerals, but their nutritional value is limited by the presence of antinutrients that reduce digestibility and micronutrient bioavailability, and by germination the level of antinutrients is substantially reduced. Only recently the benefits of germination have been recognized, and industrial processes have been developed to germinate grains and enable the change in their chemical composition.

Specifically, sprouting of grains for a limited period causes increased activities of hydrolytic enzymes, degradation of beta-glucans, improvement in the contents of certain essential amino acids and B-group vitamins, and a decrease in dry matter, starch, and antinutrients. Proteins and starch improve their digestibilities due to their partial hydrolysis during sprouting. Nevertheless, the conditions for sprouting must be carefully defined for each type of cereal. The flour from sprouted grains is nutritionally improved and it might be expected that resulting processed foods will have a substantial nutritional advantages.

An alternative to whole-grain flour is the use of different milling processes for obtaining nutritionally improved flours. Debranning or cereal-grain pearling is increasingly accepted by the milling and baking industry as a key stage in cereal processing. Pearling is the process prior to milling that removes effectively only the bran layers from the cereal grains with the application of abrasion and friction. This selective and limited removal allows nutritious parts, such as the aleurone layer to remain in the intact kernels. This pretreatment potentially could also improve milling yields of superior flour quality; besides, it lowers the capital investment costs. Nevertheless, the antioxidant capacity of pearled grains significantly decreases as the degree of pearling increases, which goes to the by-products that have higher antioxidant capacity compared to the pearled grains. The concentration of grain antioxidants is dramatically reduced during the refining process because phenolic compounds are concentrated in the outermost layers. Bran fractions, the by-product resulting from pearling, may be used as a natural source of antioxidants in the production of functional food ingredients or for the enrichment of certain products. Sequential pearling is applied to maximize the health benefits of the wheat flours, which could be used for partial replacement of the refined wheat flour (up to 10 %). The antioxidant and dietary fiber contents of the bread can be increased by enriching with pearled fractions, without affecting significantly the technological properties. Although in those strategies it must be considered the possible risk of micotoxins content when very external layers are not completely removed.

Nutritional Changes Occurring Along the Breadmaking Process

Different alternatives have been developed for adapting breadmaking to the consumer demands and for facilitating the baker's work (Rosell 2011). Breadmaking stages include mixing the ingredients, dough resting, dividing and shaping, proofing, and baking, with great variation in the intermediate stage depending on the type of bread. Breadmaking is a dynamic process with continuous physicochemical, microbiological, and biochemical changes, motivated by the mechanical-thermal action and the activity of the yeast and lactic acid bacteria together with the activity of the endogenous enzymes. During mixing, fermenting, and baking, dough is subjected to physical changes till yielding bread, in which gluten proteins are mainly responsible for bread dough structure formation, whereas starch is mainly implicated in the final textural properties and stability. During mixing is formed a continuous protein network where gluten, a non-pure protein system, has the main contribution.

Yeast and lactic acid bacteria participate along proofing and the initial stage of baking. Therefore, wheat flour, yeasts, and bacterial population of sourdoughs are the sources of different endogenous enzymes in breadmaking processes and exert an important effect on dough rheology and on the technological quality of bread (Rosell 2011). Different processing aids, namely, enzymes, are also used in breadmaking to improve the quality of the baked products by reinforcing the role of gluten, providing fermentable sugars, and/or contributing to stabilize the hydrophobic-hydrophilic interactions (Rosell and Collar 2008).

Fermented foods contribute to about one-third of the diet worldwide. Cereals are important substrates for fermented foods in all parts of the world and are staples in the Indian subcontinent, Asia, and Africa (Guyot 2012). Fermentation causes changes in food quality indices including texture, flavor, appearance, nutrition, and safety. Some benefits derived from fermentation include improvement in palatability and acceptability by developing improved flavors and textures; preservation through formation of acidulants, alcohol, and antibacterial compounds; enrichment of nutritive content by microbial synthesis of essential nutrients and improving the digestibility of protein and carbohydrates; removal of antinutrients, natural toxicants, and mycotoxins; and decreased cooking times.

The content and quality of cereal proteins may be improved by fermentation. Natural fermentation of cereals increases their relative nutritive value and available lysine. Bacterial fermentations involving proteolytic activity are expected to increase the biological availability of essential amino acids, whereas yeast fermentations mainly degrade carbohydrates. Starch and fiber tend to decrease during fermentation of cereals. During breadmaking, the total amino acid content (particularly for ornithine and threonine) increases by 64 % during mixing and undergoes a decrease of 55 % during baking, with glutamine, leucine, ornithine, arginine, lysine, and histidine being the most reactive amino acids. In general, wheat doughs started with lactic acid bacteria show a gradual increase of valine, leucine, and lysine along the fermentation, and also proline but only during the initial hours of proofing. Additionally, the action of proteinases and peptidases from lactic acid bacteria on soluble polypeptides and proteins results in the increase of short-chain peptides that contribute to plasticize the dough and give elasticity to gluten.

Fermentation also modifies the mineral content of the product, improving its bioavailability. Changes in the vitamin content of cereals with fermentation vary according to the fermentation process and the raw material used in the fermentation. The yeasted breadmaking process leads to a 48 % loss of thiamine and 47 % of pyridoxine in white bread, although higher levels of those vitamins could be obtained with longer fermentations (Batifoulier et al. 2005). Native or endogenous folates show good stability to the baking process, and even an increase in endogenous folate content in dough and bread compared with the bread flour was observed by Osseyi et al. (2001). Nevertheless, breadmaking process with yeast fermentation is beneficial for reducing the levels of phytate content with the subsequent increase in magnesium and phosphorus bioavailability (Rosell 2012).

Free amino acids in wheat flour and dough play an important role in the generation of bread flavor precursors, through the formation of Maillard compounds during baking. In fact, leucine, proline, isoleucine, and serine reacting with sugars form typical flavors and aromas described as toasty and bread-like, while excessive amounts of leucine in fermenting doughs lead to bread with unappetizing flavor. But it must be stressed that the biochemical changes that occur during breadmaking are highly dependent on the process, that is, time and temperatures for leavening, resting, and baking or cooking (Dewettinck et al. 2008). In fact, in the case of steamed bread, a decrease in the amount of amino acid takes place during production, especially alanine and tyrosine.

A special remark must be done regarding acrylamide (probable carcinogen) that has been found in starchy baked foods. No link between acrylamide levels in food and cancer risk has been established and based on the evidence to date, but some concern has risen with the first mentions. However, the Scientific Committee on Food of the European Union (EU) has endorsed recommendations made by the Food and Agriculture Organization/World Health Organization addressed to research the possibility of reducing levels of acrylamide in food by changes in formulation and processing.

Chemical Composition of Bread

Bread is the bakery specialty most frequently consumed, but different bread types result from diverse recipes, processing, shapes, and so on (Fig. 3). Analysis of the UK Government's National Diet and Nutrition Survey in 2012 suggests that bread still contributes more than 10 % of an adult's daily intake of protein, thiamine, niacin, folate, iron, zinc, copper, and magnesium; 20 % of our fiber and calcium intake; and more than 25 % of our manganese intake. Thus, eating bread can help consumers to meet their daily requirements for many nutrients, including micronutrients such as zinc and calcium.

A long-standing belief of the consumers is that bread fattens. This encourages many people to restrict, or even eliminate, bread from their diet. Nevertheless, eating patterns that include whole-grain bread could not be associated with overall obesity or excess abdominal adiposity and may be beneficial to ponderal status. Regarding dietary patterns that include refined bread, a possible relationship with excess abdominal fat has been encountered. Whole-grain cereals of various kinds are recommended due to their healthy and nutritious composition (Collar 2008).

Refined grains and cereals do not contain sufficient nutrient for maintaining the health of sedentary populations. Refined cereals, such as white flour, generally have higher glycemic index than its whole-grain counterpart; thus, consuming refined cereals causes a sharp rise in blood sugars, demanding a strong response from the pancreas. A diet full of high-glycemic-index foods has been linked to the development of diabetes. Generally, dietary pattern of people who eat large amounts of refined cereals is poor in more nutritious foods like fruits and vegetables, which increases the risk of certain diseases, such as some types of cancer. Sometimes, fiber removed during milling is added back to refined products or they are enriched with vegetable fibers, but it still remains unknown whether those resulting products have similar beneficial properties and functionality to products from whole wheat cereals.

It is recommend that cereals should be consumed at least 4–5 serves daily and that at least half of these serves should be whole grain; even as little as one serving daily reduced health risks. It must remind that the protective components (such as fiber, antioxidants, and phytoestrogens) are found in the outer layers of grains (Collar 2008).

As has been mentioned before, the basic ingredients for making bread are flour, water, yeast, and salt. Nevertheless, changes in lifestyle have conducted to modify recipes for extending shelf life using preservatives but also for improving texture with conditioners, leavening agents, shortenings, and humectants (Table 2). Conditioners include chemical compounds like emulsifiers (sodium stearoyl lactylate and monoglycerides), enzymes (alpha-amylase, lipase, xylanase, and so on), ascorbic acid, azodicarbonamide (not allowed in some countries), and calcium peroxide. Although bread is fermented by yeast and also sourdough (provides lactic acid bacteria), it is common for some kind of bread to add leavening agents, also known as raising agents or baking powders, among those sodium bicarbonate, sodium aluminum sulfate, disodium diphosphate, sodium hydrogen carbonate, monocalcium phosphate, and/or sodium acid pyrophosphate, calcium sulfate, and calcium phosphate. Other chemicals frequently used are the preservatives for extending the shelf life, like calcium propionate, potassium sorbate, methyl parabens, and/or citric acid. The combination of those ingredients led to breads with diverse nutritional composition (Table 2). The energy contribution of bread could go from 147 to twice that value in some type of breads like packaged chapatti or tortillas. Steamed bread is the one with lower energy supply per serving, due to its high moisture content. Part of those calories, from 6 % to 22 %, comes from fat, but no *trans* fats are present in bread composition. It is also important the absence of cholesterol, which was expected since cereals do not contain it. Refined flours are mainly carbohydrate, and the amount of proteins is limited; in consequence, the same pattern is observed in bread products. Carbohydrates constitute around half of the composition of breads, with the exception of steamed bread that has 50 % of that, due again to its high moisture content. The amount of dietary fibers in breads obtained from refined flour is relatively low (1–4 %). Protein content in wheat bread ranges from 3 to 9 g/100 g. Regarding minerals, bread is a major contributor to sodium intake in many countries. The salt content in bread is not really high, but due to its daily frequent consumption, it provides around 22 % of the mean salt intake from foods. In fact, in the UK, bread and breakfast cereals provide over one-third of salt in children's diets. Excessive sodium intake has been strongly associated with high blood pressure and hypertension, which can increase the risk to suffer heart disease and stroke.

Because of that, different national campaigns have been promoted to reduce the content of salt in breads as a way to reduce overall sodium intake. For instance, the Irish Bread Bakers Association (IBBA) was involved in an ongoing voluntary salt

Table 2 Ingredients used in bread recipes and nutritional composition

Ingredients	White bread (1)	Pan bread (2)	Pita bread (3)	Tortilla (4)	Chapatti (5)	Chinese steamed bread (6)
Wheat flour	x		x		x	x
Enriched unbleached flour		x		x		
Vegetable shortening				x		x
Sugar		x	x			x
Yeast	x	x	x			x
Leavening				x	x	x
Salt	x		x	x	x	
Soybean oil		x				
Sunflower oil			x			
Rapeseed oil					x	
Preservatives		x	x	x		
Conditioners		x		x		
Enzymes			x			
Rice flour				x		
Fumaric acid			x			
Calcium sulfate		x				
Low-fat yogurt					x	
Amount per 100 g						
Calories	240	250	257	279	284	147
Calories from fat	14	18	29	57	52	32
Total fat (g)	1.60	18	3	7	5.8	3.59
Saturated fat (g)	0.4			3	0.5	0.707
Trans fat (g)						
Cholesterol (mg)						
Sodium (mg)	650	571	457	525	330	549
Total carbohydrate (g)	47	54	54	51	49.4	25.06
Dietary fiber (g)	4	4	3		2.1	0.9
Sugars (g)	4	11	3		1.6	0.09
Protein (g)	8	7	9	8	7.4	3.3

Numbers following the name of the bread are used to identify their picture in Fig. 3

reduction program in partnership with the Food Safety Authority of Ireland (FSAI), which resulted in a drop by a minimum of 10 % in the breads.

There is now considerable evidence for the beneficial role played by dietary fiber in health and disease (Smith and Tucker 2011). Dietary fiber absorbs water and increases bowel bulk, resulting in a softer and larger bulk and more frequent bowel action. This provides a good environment for beneficial bacteria while decreasing the levels of harmful bacteria and the buildup of carcinogenic compounds. Cereal fiber or whole grains offer protection against heart disease. Regularly eating cereals that are rich in soluble fiber has been found to significantly reduce the amount of cholesterol in the bloodstream and reduced the risk of heart disease by 25–28 %, stroke by 30–36 %, and type 2 diabetes by 21–30 %.

Conversely, high-insoluble-fiber diet has been associated with decreased risk of developing colon cancer and diverticular disease. There is scientific evidence that people who eat whole grains regularly have lower risk of obesity, as measured by their body mass index and waist-to-hip ratios, and lower risk of many chronic diseases.

Whole grains may be eaten whole, cracked, split, ground, or milled into flour. Those forms can be incorporated in bread dough recipes to increase nutritional composition. Whole wheat breads and cereals are recommended as the best source of energy and fiber (Harris and Kris-Etherton 2010). When a food label indicates that the package contains whole grain, the "whole grain" part of the food inside the package is required to have virtually the same proportions of bran, germ, and endosperm as the harvested kernel does before it is processed, although labeling recommendations are dependent on countries' regulations. FDA defined in 1999 that "For purposes of bearing the prospective claim, the notification defined 'whole grain foods' as foods that contain 51 % or more whole grain ingredient(s) by weight" (extract). The Whole Grains Council (2006) allows certifications with the basic stamp of products that contain 8 g of whole grain per serving where 51 % of the grains are whole grain. The "100 % stamp" must only be tagged in products that contain 16 g of whole grain per serving, and all the grains in the product must be whole grain.

Incorporation of whole-grain flours increased free and bound phenolics and antioxidant capacity, apart from soluble, insoluble, and total dietary fiber fractions and total minerals. Despite the growing concern about healthy dietary guidelines, the impact of the whole-grain products in the human nutrition is still low (Siró et al. 2008). Whole grains make up about 10–15 % of grain products on supermarket shelves, within a huge presence of refined grain foods. Despite whole meal breads provide higher energy and fiber content, no great differences could be observed in the energy and fiber content due to the disparity of ingredients used for making bread (Table 3). Even fat content could be rather similar to that of refined breads. Protein content is higher than the one presented in refined breads because aleurone is also included in wholemeal wheat. Sometimes, cereal bran is added to refined wheat flour to increase the nutritional value of the flour, particularly the dietary fiber content, nonetheless bran stability somewhat limites its use in breadmaking. Different treatments like extrusion and steam cooking of bran have been suggested for improving its technological properties and also its stability during storage. Among stabilized cereal brans, stabilized rice bran is preferred due to its sweet and palatable flavor, which positively affects the sensory evaluation of the bran-containing breads. Wheat germ despite its nutritional properties is considered a by-product of the milling industry due to a high risk of rancidity. But again, certain thermal treatments such as extrusion can reduce that drawback and constitute a suitable treatment to stabilize wheat germ in bread dough or alternatively it can be used as defatted wheat germ. Extruded bran can be incorporated in wheat breads up to 10/100 g flour without significantly affecting the technological and sensorial quality of the breads.

Very often, the dietary fiber content of breads is increased by adding dietary fibers from different sources, like fruit extracts, resistant starch, beta-glucans, and

Table 3 Proximate composition of bread types containing different grains

Amount per 100 g	3 grains	Multigrain	White bread	Large enriched bread	Whole grain and flaxseed	Whole wheat
Calories (kcal)	316	256	289	250	263	279
Total fat (g)	12	3	4	3	4	3
Total carbohydrates (g)	42	47	53	53	45	49
Dietary fiber (g)	5	7		3	8	7
Proteins (g)	13	12	8	6	11	12
Sodium (mg)	395	442	632	563	421	488
% daily value						
Vitamin A						
Vitamin C						
Calcium	11	5	5	13	11	5
Thiamine	39		26	31	16	14
Riboflavin	53		16	19	5	9
Niacin	11		16	19	16	19
Folic acid	16		21	25	5	9

so on. Oat and oat or barley products containing beta-glucans are associated with many health claims including reducing blood cholesterol levels, although the physiological efficacy is dependent on the level and molecular weight of beta-glucans. Numerous commercial fibers are available in the market, which differed in solubility, particle size, hydration properties, and viscosity, among other characteristics.

Bread, like other cereal-based products, is rich in carbohydrates and produces high glycemic response. The replacement of part of wheat flour by fibers offers the chance to improve the nutritional balance of bread at the expense of readily digestible carbohydrates. In general, dietary fiber enrichment is responsible for deterioration in the expected and perceived liking of breads, although the effect might be alleviated using high-quality wheat flours.

Other trend goes to enrich bread by using protein from different sources. Legumes have been proposed as flour sources for complementing the essential amino acid balance of the cereal proteins. Legumes are rich in proteins, dietary fiber, complex carbohydrates, resistant starch, vitamins, and minerals. This practice improves the amino acid profile and increases the protein content of the bakery products made from blended flours. This approach has been selected in some countries with minor production of wheat for replacing it in bread production with the added nutritional benefit. Faba beans are among the legumes used for producing protein-rich flours. Levels of legumes used in breadmaking may reach up to 15 % wheat flour replacement without affecting dramatically the rheological properties of the dough and the sensory characteristics of the breads. That addition could lead up to 20 % increase in the protein content with minor effect on other constituents like fat.

Even with some types of breads like flatbreads, flours milled from green lentils, navy beans, and pinto beans can replace up to 25 % of the wheat flour. For instance, pita breads can be prepared with navy and pinto bean flours with coarse particle sizes with adequate color, texture, and sensory acceptance. This type of breads has been enriched with milk, eggs, other cereals, legumes, syrup, dried fruits, leafy vegetables, cassava, green banana, flaxseed flour, sesame, blackseeds, species, and dried or fresh herbs in order to increase the nutritional content in protein, vitamins and minerals, and fibers.

Other small seeds have been also added to nutritionally improve the quality of breads. For instance, fennel seeds are a source of many nutrients, like sugars, minerals, essential fatty acids, vitamins, protein, fiber, and many flavonoids. Bread with fennel seed content between 5.0 and 7.0 % shows good acceptability besides an increase in the antioxidant activity (i.e., total phenolic content, ferric reducing antioxidant power, and 2,2-diphenyl-1-picrylhydrazyl radical scavenging). Full-fat or partially defatted flaxseed meals have been added in the recipe of bread and flatbread for increasing the insoluble and soluble dietary fiber contents and amino acid (like isoleucine) and fatty acid composition (palmitic acid and stearic acid). However, when adding flaxseed, it is necessary to select the adequate processing conditions to keep the desired health attributes (Mercier et al. 2014). In fact, the benefits of flaxseed enrichment depend on the mechanical and physical properties of cereal products, enrichment level, and processing history. Flaxseed lipids are really stable under most processing and storage conditions, owing to the significant antioxidant properties of lignans; nevertheless, there is still scarce information about the impact of home handling on lipid oxidation. Concerning product shelf life, it has been also reported that cereal products enriched with flaxseed show similar or improved shelf life compared to their counterparts with no flaxseed enrichment; presumably, flaxseed may hinder starch retrogradation, contribute to moisture content retention, and delay microbial growth. Nevertheless, most cereal products containing flaxseed show lower organoleptic properties, and recommendations suggested that enrichment up to 15 % can be carried out with less impact on the sensory pattern.

Lately, consumers' interest in the role of nutrition for health and well-being seems a priority. Therefore, today, the main concern of the industry is to innovate, meet, and satisfy consumer requirements. In the baking industry, that trend has prompted the development of baked goods, keeping in mind the healthy concept. Some very novel and innovative improvements developed for enhancing the healthy benefits of breads are the processing of probiotic breads, inclusion of microencapsulated oils containing omega-3 fatty acids, and so on. In recent decades, studies on human nutrition have emphasized the importance of omega-3 and omega-6 intakes. With that purpose, different sources of those fatty acids have been investigated to be used in breadmaking. Flaxseed is a good source for such fatty acids and it has been successfully applied to obtain pan breads and Brazilian cheese roll enriched with flaxseed flour with good acceptance. Therefore, the cheese roll enriched with flaxseed presents a good alternative for aggregating nutritional and functional benefits to the conventional product. Alternatively, flaxseed oil can be used with the purpose of enriching with omega-3 in bread formulations, with the subsequent improvement of the nutritional value of wheat flaxseed-enriched breads. Also the substitution of shortenings with microencapsulated n-3 polyunsaturated fatty acids reflects an alternative for improving healthy aspects of breads.

There is a growing market for foods that contain probiotic bacteria, and a wide variety of probiotic strains are being added to an array of foods. The ability of probiotic strains to survive the conditions of the manufacturing processes (e.g., temperature, pH, oxygen, etc.) is the main impediment food manufacturers must overcome. The development of functional breads containing viable microorganisms has been a challenge due to the high temperature reached during baking, which results in significant losses in probiotic viability. Successful probiotic breads have been obtained using thermostable *Lactobacillus* and also incorporating *Lactobacillus acidophilus* in microcapsules applied to bread surface through edible coatings; specifically, those have been sprayed on partially baked breads to minimize the impact of the baking temperature on the microorganism viability. The heat stability of probiotic *Bacillus subtilis* R0179 has permitted its addition in bread and cookie formulations with adequate survival. Another probiotic that has been recommended for probiotic breadmaking is *Lactobacillus rhamnosus* R0011, which, despite its heat sensitivity, when sprayed on baked bread shows good stability over the shelf life of the product. In the USA, *B. subtilis* and *L. rhamnosus* are entitled for structure/function claims, which can be used in baked products.

Probiotic bread was launched in the USA by a baking company claiming that a health and wellness bread contains probiotics, which contributes to the health and balance of the digestive system; besides, it was made with whole wheat flour, flaxseeds, sunflower seeds, chia seeds, and millet for added nutritional value.

Composition of Other Bakery Products

Apart from bread, other common bakery products include muffins, cookies, crackers, pastries, and croissants. Converse to the basic bread composition, sweet bakery products are obtained from very rich recipes, with numerous ingredients. Those products are in general hypercaloric due to their high content of sugar and fatty ingredients. Some sweet products (cookies, croissants, pastries, and muffins/cakes) have been selected for reviewing ingredients used in their recipe and also for showing their nutritional composition (Tables 4, 5, and 6).

Cookies, also referred as biscuits in some parts of the world, have a great diversity of composition. A variety of ingredients is used, which determine their sensory perception but mainly texture during fracture. Table 4 shows different kinds of biscuits; they mainly differ in fat content and therefore in their texture when cutting. Wheat flour is usually the main ingredient of this kind of products, followed by fat (from animal or vegetable sources) and sugar. Sugar could be added as sucrose, glucose, or fructose syrup. This type of products is leavened with baking powders, generally ammonium bicarbonate and sodium bicarbonate. Minor ingredients comprise salt, dairy ingredients, and flavors like vanilla. Cookies have very low moisture content (4–8 %) and water activity, which inhibits microbial growth during their storage. Regarding their nutritional composition, as can be expected from the fat-rich recipe, they are highly caloric (from 400 to 500 kcal/100 g) (Table 4). No *trans* fats are necessary for processing cookies. Cholesterol is present whenever fats from animal sources are used in the recipes. Cookies have higher content of carbohydrates than bread due to the high sugar content, and fiber could greatly vary depending on whether fibers were incorporated in the recipe. Protein content is usually derived from the cereal flour and some traces of dairy ingredients. Legume flours are also added for cookie making, with significant improvement of their nutritional quality.

Other caloric products are croissants and pastries, which require a high amount of fat for reaching a layered structure. Examples of composition are given in Table 5. Wheat flour is still the main ingredient closely followed by fat (non-hydrogenated or partially hydrogenated vegetable margarine). In addition, croissants contain sugar, mono- and diglycerides, lecithin, sugar, yeast, salt, and preservatives, whereas pastries could contain mono- and diglycerides, lecithin, and syrup. Energy provided by 100 g of croissants or pastries is around 400 kcal, with a great contribution of fats to that caloric value. High cholesterol content could be present when animal fats are used. The amount of carbohydrates is low compared with the rest of bakery products and proteins generally from the flour content.

Muffins and cakes admit thousands of variations in their recipes, either due to raw materials or fillings, toppings, and so on. In this type of products, egg proteins and sugar play a really important role for determining their internal structure and, in consequence, their mouthfeel and taste. Some examples of composition can be displayed in Table 6. In muffins and cakes, the main ingredient is wheat flour closely followed by oil and eggs. Since they are rich in fat and oils, emulsifiers are usually present in their composition to improve texture. Lecithin, mono- and diglycerides, and sodium stearoyl lactylate are used as emulsifiers. Preservatives and also gums like xanthan gum, guar gum, or modified celluloses are commonly present for extending the shelf life and the freshness perception. Consumption of these products supply a high amount of calories mainly from fat and sugars, and the cholesterol content is dependent on the type of fat used in their processing. Usually, they supply high amounts of sodium and very low levels of fibers.

Non-bread bakery products are usually rich in fats and sugars; thus, they are conceived for consumer's pleasure and healthiness is somewhat secondary. Nevertheless, even in this type of products, consciousness about improving their nutritional profile is being sited. Tendencies are mainly focused on improving the fats composition and reducing the caloric intake from sugars. Usually, sweet bakery products contain a high amount of saturated fats with *trans*-fatty acids, which are needed for the handling and texture of laminated doughs. However, in the last decade, there is sufficient scientific information supporting the prejudicial effect of the *trans*-fatty acids on the blood lipid metabolism and the development of arteriosclerosis and cardiovascular diseases. In consequence, great efforts have been concentrated in looking for functional replacements of those fatty

Table 4 Ingredients used in cookie recipes and their nutritional composition

Ingredients	Basic cookies 	Butter cookies 	Cookies – digestive 
Wheat flour	x	x	
Whole wheat flour			x
Vegetable fat	x		x
Butter		x	
Sugar	x	x	x
Glucose syrup	x		x
Fructose syrup	x		x
Milk powder	x		
Baking soda	x	x	x
Salt	x	x	x
Aroma	x		
Sodium bisulfite	x		
BHA (butylhydroxyanisole)	x		
Vanilla		x	
Eggs		x	
Soy lecithin		x	

(*continued*)

Table 4 (continued)

Ingredients	Basic cookies 	Butter cookies 	Cookies – digestive 
Amount per 100 g			
Calories (kcal)	433	519	483
Calories from fat	159	222	189
Total fat (g)	18	26	21
Saturated fat (g)	5	15	10
Trans fat (g)			
Cholesterol (mg)		56	<5
Sodium (mg)		370	0 .65
Total carbohydrate (g)	72	67	66
Dietary fiber (g)	7		3
Sugars (g)	19	22	18
Protein (g)	7	4	6

Table 5 Ingredients used in croissant and pastry recipes and their nutritional composition

Ingredients	Croissants 	Puff pastry sheets 
Enriched bleached wheat flour	x	
Unbleached enriched wheat flour		x
Vegetable margarine	x	
Vegetable shortening		x
Water	x	x
Sugar	x	
Monoglycerides	x	x
Diglycerides	x	x
Soy lecithin	x	x
Citric acid	x	
Potassium sorbate	x	
Flavor	x	
Vitamin A palmitate	x	
Vitamin D	x	
Beta-carotene color	x	x
Soybean oil	x	
Yeast	x	
Salt	x	x
Sodium propionate	x	
Fructose corn syrup		
Wheat gluten		x
Amount per 100 g		
Calories (kcal)	438	415
Calories from fat	168	244
Total fat (g)	21	27
Saturated fat (g)	12	15
Trans fat (g)		
Cholesterol (mg)	67	
Sodium (mg)	467	341
Total carbohydrate (g)	46	34
Dietary fiber (g)	3	<2
Sugars (g)	11	2
Protein (g)	8	7

Table 6 Ingredients used in croissant and pastry recipes and their nutritional composition

Ingredients	Muffin 	Cake 
Wheat flour	x	x
Sugar	x	x
Soybean oil	x	x
Canola oil	x	
Eggs	x	x
Water	x	x
Cultured buttermilk	x	
Margarine	x	
Baking powder	x	x
Dextrose	x	
Whey milk	x	
Salt	x	x
Monoglycerides	x	x
Diglycerides	x	x
Sodium stearoyl lactylate	x	x
Xanthan gum	x	
Sodium bicarbonate	x	
Natural flavor	x	x
Artificial flavor	x	x
Citric acid	x	
Soy lecithin	x	x
Food starch modified		x
Partially hydrogenated soybean oil		x
Cottonseed oil		x
Palm oil		x
Nonfat milk		x
Wheat gluten		x
Dextrose		x
Cornstarch		x
Soy flour		x
Sodium propionate		x
Calcium sulfate		x

(*continued*)

Table 6 (continued)

Ingredients	Muffin 	Cake 
Cellulose gum		x
Buttermilk powder		x
Beta-carotene color		x
Potassium sorbate		x
Coconut oil		x
Amount per 100 g		
Calories	364	400
Calories from fat	162	188
Total fat (g)	17	21
Saturated fat (g)	3	4
Trans fat (g)	0	0
Cholesterol (mg)	56	65
Sodium (mg)	343	365
Total carbohydrate (g)	48	51
Dietary fiber (g)	1	<1
Sugars (g)	31	28
Protein (g)	5	5

acids. The usual fat replacers can be classified into three categories: carbohydrate based, protein based, and fat based. Inulin, polydextrose, and oligofructose have been proposed as fat mimetics in cookie making or inulin in muffin making. Another alternative is the use of edible emulsions of water in fat in the presence of a humectant for obtaining low-fat products.

In addition, fat- and sugar-reduced cookies have been also developed. With that purpose, fat mimetics have been used for partial fat replacement and polyols, like lactitol, sorbitol, and maltitol, for sugar replacement. With this strategy, up to a 50 % fat replacement could be obtained, but those replacements usually result in hard and brittle cookies which do not have a proper expansion after baking. In doing those fat replacements, it must be taken into account that before new ingredients can be used in food, they must either be self-affirmed to be generally recognized as safe (GRAS) or approved for such use by the Food and Drug Administration (FDA) under a food additive petition. A GRAS substance is defined as one generally recognized by scientific experts to be safe for specific uses on the basis of an extensive history of use or on the basis of published scientific evidence. These procedures seek to ensure the safety of foods for consumers of all ages. The majority of fat reduction ingredients currently used are considered to be GRAS.

Among other alternatives for improving the nutritional profile of those products is the use of wheat germ up to 20 % for cake making. Wheat germ addition increases the ash, protein, fat, and mineral contents (Ca, Cu, Fe, Mg, Mn, P, K, and Zn) of the cakes, although the addition of emulsifiers is advisable for keeping physical and sensory quality.

Bakery Products in Fortification Programs

Bakery foodstuffs constitute staple food in many countries, and as such, they have been selected as the best carriers of micronutrients in fortification programs when some special requirements are detected in the population (Baurenfiend and DeRitter 1991). Properly used fortification can be a strategy to control nutrient deficiencies (Allen et al. 2006). Fortification may be the easiest, cheapest, and best way to reduce a deficiency problem. Nevertheless, some concerns related to proliferation and excessive promotion of the fortified foods have risen, because that could lead to a simultaneous replacement of the non-fortified foods in the diet and to avoid situations of excessive intake of certain micronutrients (Rosell 2008). The pros and cons of fortification need to be balanced in each circumstance (Rosell 2004).

Fortification can be defined as the addition of one or more vitamins and/or minerals to a food, regardless of its usual content in the food, in order to prevent or correct a demonstrated deficiency of one or more vitamins and/or minerals in the population or specific population groups or to improve the nutritional status of the population and dietary intakes of vitamins or minerals due to changes in dietary habits, and that addition must be based on generally accepted scientific knowledge of the role of vitamins and minerals in health (Rosell 2004, 2008). Additions are carried out based on generally accepted scientific knowledge of the role of vitamins and minerals in attaining good health. Foods are fortified for the following reasons:

- To prevent or correct a demonstrated deficiency of one or more vitamins and/or minerals in the population or specific population groups
- To improve the nutritional status of the population and dietary intakes of vitamins or minerals due to changes in dietary habits

Enrichment is a term usually interchanged with fortification that should be equivalent to restoration of the vitamin and mineral levels lost during manufacturing, storage, and handling.

Cereal fortification methods have been developed to restore the nutrients that have been removed during milling and to improve the nutrient intake level of a specific population (Poletti et al. 2004). In addition, some efforts have focused on enhancing the nutritional quality of the crops through biofortification strategies, because half of the world population suffers from malnutrition with respect to iron, zinc, and selenium. For instance, selenium is an essential micronutrient for humans, and it is deficient in at least one billion people worldwide (Lim et al. 2013). Plants and plant-derived products transfer the soil-uptaken selenium to humans; thus, the cultivation of plants enriched in selenium can be an effective way to improve the selenium status on humankind (Pérez-Massot et al. 2013). Therefore, controlled agronomic biofortification of wheat crops for flour and bread production could provide an appropriate strategy to increase the intake of some minerals.

Fortification of flour is usually carried out in mills, where the nutrient mixture is blended with the flour. Milling produced a uniform distribution of fortificants with no significant separation during packaging or transportation. In doing so, it is critical the definition of the nutrients and the levels to be added must be based on the nutritional needs and deficiencies of the population, the common consumption of the fortifiable flour, the sensory and physical aspects, and economic cost. The addition of B vitamins, iron, and calcium is a common practice in some developed countries (Rosell 2008, 2014). However, the nutrient added must have good stability during storage, and in defining the levels to be added must be considered the extraction rate during milling.

Flour fortification has become mandatory in numerous countries, where specific legislation has been set up to define the list of foods acting as carriers, the minerals and vitamins to be added back, the levels, and also the chemical compounds allowed to supply those minerals and vitamins (Rosell 2008, 2012, 2014). In fact, enriched flours might contain, apart from the wheat flour, niacin, reduced iron, thiamine mononitrate, riboflavin, and folic acid. The success of fortification programs always depends on good control, so they should be set up, regulated, and enforced by the national governments.

There are some criteria or principles for fortification that should be met for those when planning to fortify one or more foods to improve nutritional status. They apply mainly to fortification as a strategy to tackle micronutrient deficiencies. Those criteria are (i) known nutrient deficiency in the population, (ii) wide consumption of the food to be fortified among the at-risk population, (iii) suitability of the food and nutrient together, (iv) technical feasibility, (v) limited number of food manufacturers, (vi) no substantial increase in the price of the food, and (vii) legislation. When a fortification program is established, continuous monitoring and control of the fortification, in order to determine the success of the strategy, are necessary.

Food fortification offers an important strategy to help control, in particular, the three main micronutrient deficiencies, namely, deficiencies of iodine, vitamin A, and iron (Ranum et al. 2001). In developing countries, the greatest priority should be given to fortification with these nutrients. With iodine, fortification alone, in the form of salt iodization, is often the only strategy used. With vitamin A and iron, fortification should be used in combination with, not to the exclusion of, other interventions (Hurrell et al. 2010). It must be stressed that also compounds interactions might enhance or shield the effectiveness of the fortification. For instance, inhibitors of iron absorption include phytate, polyphenols, soy protein, and calcium, and enhancers include animal tissue and ascorbic acid. Organic acids, such as citric acid, malic acid, and tartaric acid, are promoters of Fe bioavailability. Sensory analysis must be always considered because differences in the overall quality of breads prepared with fortified flour with the addition of chemical sources of minerals might affect sensory characteristics.

Fortification has been also very effective to reduce the deficiency prevalence of the following micronutrients: niacin, thiamine, riboflavin, folate, vitamin C, zinc and calcium. Only phytate and soy protein inhibit zinc absorption, although also the consumption of black tea simultaneously with fortified bread significantly reduces the zinc absorption. The supplementation of B vitamins to flour is faced with the problem of low stability of these compounds during storage. Hence, higher effectiveness is obtained when B vitamins are added at the bakery rather than at the mill.

B vitamins (thiamine, B_1; riboflavin, B_2; and niacin, B_3) are supplemented to cereal flours in developed countries to ensure the adequate intake of those nutrients through, for instance, the consumption of fortified bread. Pyridoxine or vitamin B_6 is also supplemented to wheat for obtaining fortified bread, although bioavailability decreases by 5–10 % when it is used in whole wheat bread (Leklem et al. 1980). Vitamin B_{12}-fortified bread is a good source of this vitamin (Selhub and Paul 2011); with its consumption even the elderly can ensure the efficient absorption of vitamin B_{12} (Rusell et al. 2001). Other less exploited but convenient and efficient strategy of increasing the levels of vitamins is the use of selected natural riboflavin-overproducing strains. For instance, riboflavin-overproducing strains of *Lactobacillus plantarum* can be used in breadmaking (by means of sourdough fermentation) to enhance bread vitamin B_2 content.

Bread has also been fortified with vitamin D using cholecalciferol, showing good dispersion in the breads and stability. This fortified bread increases serum 25-hydroxyvitamin D concentration as effectively as the cholecalciferol supplement, without affecting serum intact parathyroid hormone concentration or urinary calcium excretion (Natri et al. 2006). Therefore, fortified bread is a safe and feasible way to improve vitamin D nutrition.

Folic acid is another B vitamin added to cereals due to its great contribution to the population health. In 1996, the American Food and Drug Administration concluded that 1,000 μg folate/day is the safe upper limit of folate intake for the general population. The fortification level was established at 140 μg folic acid/100 g for enriched cereal-grain products; that fortification provides 10 % of the daily value per bread serving. This level of fortification was chosen to assist women of reproductive age in increasing their folic acid intake by a daily average of 140 μg folic acid. Currently, folic acid mandatory fortification is already used in more than 50 countries, including the USA and Canada, where research suggests it reduces the rate of neural tube defects by 25–50 %. It seems that this fortification will be imminently mandatory in the UK.

In addition, it has been described that the consumption of bread fortified with 2.5 % elemental calcium concentration is an effective way for ameliorating the hyperphosphatemia without inducing hypercalcemia (Babarykin et al. 2004). Therefore, calcium-fortified bread can be consumed as a treatment of uremic hyperphosphatemia. Calcium-fortified pita bread was similar to its regular counterpart (Ziadeh et al. 2005).

Special Bakery Products Developed for Targeted Groups

There is some population with food ailments associated to cereals, mainly gluten. This type of products requires special attention because their composition is completely different than the ones obtained directly from cereals. This section will describe the chemical composition of gluten-free breads and other types of breads that have been developed to meet the requirements of targeted groups.

To be in a healthy state, the maintenance of energy balance is necessary. Positive energy balance in favor of the energy ingested leads to obesity, regardless of the composition of excess energy. The frequency of obesity has increased dramatically in many developed and developing countries. There is great concern among health authorities because of the relationship between obesity and some other diseases like diabetes, cardiovascular disease, and other chronic diseases of lifestyle. A tactic to fight that trend is to increase carbohydrate consumption (in replacement of fat) because carbohydrate provides only 4 kcal per gram compared with 9 kcal per gram for fat. High-fiber foods and whole-grain breads and cereals can be an effective part of any weight loss program (Collar 2008) since they have slower digestion and induce a feeling of satiety.

When considering cereals and health, it is important to introduce that a percentage of population shows intolerance to gluten intake like celiac disease. Peptides released during gluten digestion are responsible for the intolerance in genetically predisposed individuals. Up to date, the unique effective treatment is dietary therapy, avoiding the intake of gluten-containing foods (García-Manzanares and Lucendo 2011). A general consensus has been reached that the cereals considered gluten-free safe are rice and corn (Rosell and Marco 2008). Wheat, spelt, kamut, rye, triticale, barley, and probably oats and hybrids of these grains must be eliminated from the diet. Gluten-sensitive individuals can tolerate buckwheat, millet, amaranth, quinoa, teff, and/or sorghum. To mimic the viscoelastic properties of gluten, a large number of flours and starches as well as many ingredients such as gums, enzymes, and proteins from different sources have been used for making bread resembling the structure, mouthfeel, acceptability, and shelf life of gluten breads (Rosell 2007, 2013).

The absence of gluten in natural and processed foods, despite being the cornerstone treatment for celiac disease, may lead to nutritional consequences, such as deficits and imbalances. Nutrition counseling for celiac disease has focused on the foods to avoid when sticking to gluten-free diet, but the nutritional quality of gluten-free products must enter into the picture. There are growing concerns over the nutritional adequacy of the gluten-free dietary pattern because it is often characterized by an excessive consumption of proteins and fats and a reduced intake of complex carbohydrates, dietary fiber, vitamins, and minerals (Penagini et al. 2013). As a consequence, the long-life adherence to gluten-free products has been associated to undernourished and also mineral deficiencies that could lead to anemia, osteopenia, or osteoporosis. In recent years, attention has focused on the nutritional quality of gluten-free products available in the market, which are of lower quality and poorer nutritional value than their gluten-containing counterparts. Gluten-free breads are mainly starch based and contain low amounts of vitamins, minerals, and in particular dietary fiber, but with great variation among marketed products (Rosell 2014). Gluten-free breads have very low contribution to the recommended daily protein intake, with a high contribution to the carbohydrate dietary reference intake. In general, gluten-free breads show great variation in the nutrient composition, being starch-based foods low in proteins and high in fat content, with high glycemic index. Besides that, gluten intolerance, like celiac disease, induces an intestinal lesion that leads to various deficiencies of nutrients, vitamins, and dietary minerals, being ferropenia, vitamin B_{12}, folic acid, and fat-soluble vitamin deficiencies especially frequent. This proximal location in the small intestine often results in malabsorption of calcium, iron, folic acid, and fat-soluble vitamins. Patients newly diagnosed or inadequately treated often have low bone mineral density, which appears to be directly related to the intestinal malabsorption. Osteomalacia or osteopenia is secondary to the reduced calcium absorption, caused by atrophy of the intestinal villi, and/or to a vitamin D deficiency, leading to secondary hyperparathyroidism; because of that, osteoporosis is a frequent complication accompanying celiac disease. Those patients are particularly prone to have low bone density and high risk of fractures. Therefore, a redesign of the gluten-free bakery goods is needed for obtaining gluten-free baked products with similar nutritional composition to that of their gluten counterparts. Those products would allow celiac patients and/or population with other allergic reactions and intolerances caused by proteins or another component of cereals to meet dietary guidelines without changing their dietary pattern.

In the last decade, new recipes and ingredient composition are proposed for obtaining nutritional balances or enriched gluten-free breads. Additionally, the supplementation of gluten-free bread with proteins has been a technological strategy for improving the protein network and for mimicking the viscoelastic properties of gluten proteins in wheat-containing breads. Protein enrichment can be obtained using legume flours, egg proteins, or dairy proteins at different percentages (0 %, 10 %, 20 %). Eggs are frequently avoided because gluten-intolerant patients are very often intolerant to albumin. Dairy powders can be added up to 12 % because higher levels provoke great detrimental effect on the technological properties. Legume flours are useful for protein and fiber enrichment of bakery foodstuff, like gluten-free cakes. Nevertheless, their effect on the technological and sensorial quality is dependent on the legume origin. Legumes significantly enhance the protein content and its availability, and the total dietary fiber content, besides its incorporation, reduces the glycemic index of the resulting product. Moreover, lentil-containing cakes led to low-density batters and high specific volume.

Gluten-free bakery products have not been immune to the fiber enrichment trend. With that aim, different fibers have been added to this type of products. Usually, whole wheat grains are not used for making gluten-free products due to technological limitations for obtaining low dense and porous structures; because of that, fibers from different sources are being preferred for enriching these products. Fibers from cereal bran, legumes' outer layer, and processing by-products of apple and potato industry have been used for enriching wheat cakes and muffins. Rice bran up to 10 % or therein fractions have been proposed for increasing the protein, fat, and dietary fiber contents; moreover, they supply insoluble and soluble dietary fiber. Soluble dietary fibers also contribute to the technological quality of gluten-free breads, improving color, specific volume, softness of crumb, and crumb porosity. Insoluble and soluble fibers or their blends are recommended for making gluten-free layer cakes enriched in soluble and insoluble fibers of acceptable quality, without compromising excessively the specific volume and the crumb texture. Due to health benefits derived from the intake of fiber-containing foods and the recommendation to still balance the consumption of soluble and insoluble fibers, a blend of insoluble fiber with soluble fibers like inulin or guar gum is advisable for replacing up to 20 g/100 g of gluten-free flour when making enriched gluten-free layer cakes.

Gluten-free flours have not been subjected to regulations regarding fortification programs; because of that, numerous gluten-free products are mineral and vitamin poorer than their wheat counterparts. The fortification of gluten-free bread with different sources of minerals like calcium has been a topic of research, owing to the impact of calcium on the health of gluten-intolerant patients. Calcium lactate, calcium citrate, calcium chloride, and calcium carbonate are among the proposed sources of elementary calcium for gluten-free breads. All those sources led to fortified breads, calcium carbonate followed by calcium citrate is the most recommended salt for obtaining calcium fortification of gluten-free breads based on the sensory acceptance of breads. The same approach has been carried out with different iron compounds, although elemental iron seems to be more stable and with less impact on sensory and technological characteristics of the gluten-free breads.

Other allergies are related to the intake of dairy, peanuts, tree nuts, egg, soy, fish, or shellfish – the allergens that with wheat/gluten account for 90 % of all food allergic reactions in the USA. To give response to those consumers with some type of allergies, there are products in the market free from lactose and dairy compounds, eggs, and so on. The presence of those products is still very limited and this market is not a strong driven force as occurs in the gluten-free products.

Conclusion and Future Directions

The market of baked goods is always increasing and thousands of new products are launched yearly. Cereal baked goods are still an important source of nutrients worldwide, owing to their presence in almost all daily meals. Those products are the main sources of complex carbohydrates and proteins, besides B vitamins and minerals like calcium, iron, potassium, magnesium, manganese, phosphorus, and zinc. Nevertheless, a great part of those is lost during milling; because of that, whole wheat products are recommended. When considering baked products, a distinction must be made between bread and the rest of baked products, since their chemical composition is considerably different, moreover, on the fat content.

Despite the availability of the increasing number of bakery products, recipes are changing and the nutritional profile of the baked products has been changing over the last decades. This fact together with the changes underwent in the consumers' lifestyle and also the increasing detection of diverse ailments obey to reconsider carefully the recipes or formulations used for making baked products. Lately, enrichment and fortification are gaining popularity for providing more nutritious baked products. With this purpose, additional raw materials like pseudocereals, legumes, and other protein sources are being included in the recipes. In addition, having nutrition awareness in mind, recipes have also been modified for healthier ingredients or additives, which is really important in baked goods rich in fat constituents. Simultaneously, the special requirements needed by consumers when subjected to dietetic therapies make necessary the design and development of tailored baked goods that meet sensory desires and nutritional requests. It is envisaged that during the next decade, nutrition is still going to govern the driven forces of the food market and nutrition claims will try to attract consumers.

Acknowledgments Author would like to thank the Spanish Ministry of Economy and Sustainability (Project IPT-2012-0487-060000), the European Regional Development Fund (FEDER) and the Generalitat Valenciana (Project Prometeo 2012/064).

Cross-References

- ► Chemical Composition of Cereals and Their Products
- ► Chemical Composition of Eggs and Egg Products
- ► Chemical Composition of Fat and Oil Products
- ► Chemical Composition of Sugar and Confectionery Products

References

Aisbitt B, Caswell H, Lunn J (2008) Cereals - current and emerging nutritional issues. J Nutr Bullet 33(3):169–185

Allen L, Benoist B, Dary O, Hurrell R (2006) Guidelines on food fortification with micronutrients. World Health Organization and Food and Agriculture Organization of the United Nations. http://www.who.int/nutrition/publications/guide_food_fortification_micronutrients.pdf. Accessed 10 Dec 2013

Babarykin D, Adamsone I, Amerika D, Spudass A, Moisejev V, Berzina N, Michule L, Rozental R (2004) Calcium-enriched bread for treatment of uremic hyperphosphatemia. J Renal Nutr 14:149–156

Batifoulier F, Verny MA, Chanliaud E, Remesy C, Demigne C (2005) Effect of different breadmaking methods on thiamine, riboflavin and pyridoxine contents of wheat bread. J Cereal Sci 42:101–108

Baurenfiend JC, DeRitter E (1991) Foods considered for nutrient addition: cereal grain products. In: Baurenfiend JC, LaChance PA (eds) Nutrient additions to food, technological and regulatory aspects. Food and Nutrition Press, Connecticut, pp 143–209

Borneo R, León AE (2012) Whole grain cereals: functional components and health benefits. Food Funct 3(2):110–119

Collar C (2008) Novel high and whole grain breads. In: Hamaker B (ed) Technology of functional cereal products. Woodhead, Cambridge, UK, pp 184–214

Dewettinck K, Van Bockstaele F, Kühne B, Van de Walle D, Courtens TM, Gellynck X (2008) Nutritional value of bread: influence of processing, food interaction and consumer perception. J Cereal Sci 48(2):243–257

EFSA Comprehensive European Food Consumption Database (2011) http://www.efsa.europa.eu/en/datexfoodcdb/datexfooddb.htm. Accessed 14 Mar 2014

Food and Drug Administration (2006) FDA provides guidance on "whole grain" for manufacturers. Available at website: http://www.registrarcorp.com/fda-food/labeling/regulations.jsp?lang=en. Accessed 17 Mar 2014

FAOSTAT (2014) Food and Agricultural Organization of United Nations. http://faostat3.fao.org/faostat-gateway/go/to/download/FB/FB/E. Accessed 10 Mar 2014

García-Manzanares Á, Lucendo AJ (2011) Nutritional and dietary aspects of celiac disease. Nutr Clin Pract 26(2):163–173

Guyot J (2012) Cereal-based fermented foods in developing countries: ancient foods for modern research. Int J Food SciTechnol 47(6):1109–1114

Harris KA, Kris-Etherton PM (2010) Effects of whole grains on coronary heart disease risk. Curr Atheroscler Rep 12(6):368–376

Hurrell R, Ranum P, de Pee S, Biebinger R, Hulthen L, Johnson Q, Lynch S (2010) Revised recommendations for iron fortification of wheat flour and an evaluation of the expected impact of current national wheat flour fortification programs. Food Nutr Bull 31(1 Suppl):S7–S21. http://www.ncbi.nlm.nih.gov/pubmed/20629349

Lambert JL, Le-Bail A, Zuniga R, Van-Haesendonck I, Van-Zeveren E, Petit C, Rosell CM, Collar C, Curic D, Colic-Baric I, Sikora M, Ziobro R (2009) The attitudes of European consumers toward innovation in bread; interest of the consumers toward selected quality attributes. J Sens Stud 24:204–219

Leklem JE, Miller LT, Perera AD, Pefers DE (1980) Bioavailability of vitamin B-6 from wheat bread in humans. J Nutr 110:1819–1828

Lim KHC, RiddellLJ NCA, Booth AO, Szymlek-Gay EA (2013) Iron and zinc nutrition in the economically-developed world: a review. Nutrients 5(8):3184–3211

McKevith B (2004) Nutritional aspects of cereals. Nutr Bull 29(2):111–142

Mercier S, Villeneuve S, Moresoli C, Mondor M, Marcos B, Power KA (2014) Flaxseed-enriched cereal-based products: a review of the impact of processing conditions. Compr Rev Food Sci Food Safety 13(4):400–412

Natri AM, Salo P, Vikstedt T, Palssa A, Huttunen M, Karkkainen MUM, Salovaara H, Piironen V, Jakobsen J, Lamberg-Allardt CJ (2006) Bread fortified with cholecalciferol increases the serum 25-hydroxyvitamin D concentration in women as effectively as cholecalciferol supplement. J Nutr 136:123–127

Osseyi ES, Wehling RL, Albrecht JA (2001) HPLC determination of stability and distribution of added folic acid and some endogenous folates during breadmaking. Cereal Chem 87:375–378

Penagini F, Dilillo D, Meneghin F, Mameli C, Fabiano V, Zuccotti GV (2013) Gluten-free diet in children: an approach to a nutritionally adequate and balanced diet. Nutrients 5(11):4553–4565

Pérez-Massot E, Banakar R, Gómez-Galera S, Zorrilla-López U, Sanahuja G, Arjó G, Zhu C (2013) The contribution of transgenic plants to better health through improved nutrition: opportunities and constraints. Genes Nutr 8(1):29–41

Poletti S, Gruissem W, Sautter C (2004) The nutritional fortification of cereals. Curr Opin Biotechnol 15(2):162–165

Ranum P, Lynch S, Bothwell T, Hallberg L, Hurrell R, Whittaker P, Rosado JL, Davidsson L, Mannar V, Walter T, Fairweather-Tait S, Dary O, Rivera J, Bravo L, Reddy M, Garcia-Casal MN, Hertrampf E, Parvanta I (2001) Guidelines for iron fortification of cereal food staples. SUSTAIN, Washington, DC. Published online at www.sustaintech.org/publications/pubm7.pdf

Rosell CM (2004) Fortification of grain based foods. In: Wrigley C, Corke H, Walker C (eds) Encyclopedia of grains science. Elsevier, UK

Rosell CM (2007) Enzymatic manipulation of gluten-free bread. In: Gallagher E (ed) Gluten-free food science and technology. Blackwell, Oxford, UK

Rosell CM (2008) Vitamin and mineral fortification of bread. In: Hamaker B (ed) Technology of functional cereal products. Woodhead, Cambridge, UK, pp 336–361

Rosell CM (2009) Trends in breadmaking: low and subzero temperatures. In: Passos ML, Ribeiro CL (eds) Innovation in food engineering: new techniques and products. Taylor and Francis/CRC Press, Boca Raton, pp 59–79

Rosell CM (2011) The science of doughs and bread quality. In: Preedy VR, Watson RR, Patel VB (eds) Flour and breads and their fortification in health and disease prevention. Academic Press/Elsevier, London/Burlington/San Diego, pp 3–14

Rosell CM (2012) The nutritional enhancement of wheat flour and related products. In: Cauvain S (ed) Bread-making: improving quality, 2nd edn. Woodhead, Cambridge, UK, pp 687–710

Rosell CM (2013) Alimentos sin gluten derivados de cereales. In: Rodrigo L, Peña S (eds) Enfermedad Celiaca, Omnia Monográficos, Spain, pp 447–462. doi: 10.3926/oms.16

Rosell CM (2014) Fortification of grain based foods. In: Wrigley C, Corke H, Walker C (eds) Encyclopedia of grains science, 2nd edn. Elsevier, Oxford, UK

Rosell CM, Collar C (2008) Effect of various enzymes on dough rheology and bread quality. In: Porta R, Di Pierro P, Mariniello L (eds) Recent research developments in food biotechnology. Enzymes as additives or processing aids. Research Signpost, Kerala, India, pp 165–183

Rosell CM, Marco C (2008) Rice. In: Arendt EK, Dal Bello F (eds) Gluten free cereal products and beverages. Elsevier, London, UK, pp 81–100

Rusell RM, Baik H, Kehayias JJ (2001) Older men and women efficiently absorb vitamin B-12 from milk and fortified bread. J Nutr 131:291–293

Selhub J, Paul L (2011) Folic acid fortification: why not vitamin B12 also? Biofactors 37 (4):269–271

Siró I, Kápolna E, Kápolna B, Lugasi A (2008) Functional food, product development, marketing and consumer acceptance-A review. Appetite 51(3):456–467

Smith CE, Tucker KL (2011) Health benefits of cereal fibre: a review of clinical trials. Nutr Res Rev 24(1):118–131

WHO, FAO, UNICEF, GAIN, MI, FFI (2009) Recommendations on wheat and maize flour fortification. In: Meeting report: interim consensus statement. World Health Organization, Geneva. http://www.who.int/nutrition/publications/micronutrients/wheat_maize_fort.pdf. Accessed 10 Dec 2013

Whole Grain Council, Definition of whole grains (2004) Available at website: http://wholegrainscouncil.org/find-whole-grains. Accessed 15 Mar 2014

Yu LL, Tsao R, Shahidi F (2012) Cereals and pulses: nutraceutical properties and health benefits. Wiley-Blackwell, Ames

Ziadeh G, Shadarevian S, Malek A, Khalil J, Haddad T, Haddad J, Toufeili I (2005) Determination of sensory thresholds of selected calcium salts and formulation of calcium-fortified pocket-type flat bread. J Food Sci 70:548–552