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Functional Beverages: The Emerging Side of Functional Foods

Commercial Trends, Research, and Health Implications

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Abstract: In recent times, there has been growing recognition of the key role of foods and beverages in disease prevention and treatment. Thus, the production and consumption of functional foods has gained much importance as they provide a health benefit beyond the basic nutritional functions. At present, beverages are by far the most active functional food category because of convenience and possibility to meet consumer demands for container contents, size, shape, and appearance, as well as ease of distribution and storage for refrigerated and shelf-stable products. Moreover, they are an excellent delivering means for nutrients and bioactive compounds including vitamins, minerals, antioxidants, ω-3 fatty acids, plant extracts, and fiber, prebiotics, and probiotics. However, in most cases, specific concerns have been raised over their safety. This review reports on the scientific advances in the emerging area of functional beverages with a focus on commercially available products, as well as on the potential health benefits related to their consumption.

Keywords: enriched beverages, functional, health claims, nutritional claims, prebiotic, probiotic

Introduction

Over the last decade, demand for "healthy" foods and beverages has increased in many parts of the world (Ozen and others 2012) and the diffusion of functional foods throughout the market has blurred the distinction between pharma and nutrition (Eussen and others 2011).

The idea of health-promoting foods is not new: Hippocrates wrote 2400 years ago "Let food be thy medicine and medicine be thy food" (Otles and Cagindi 2012), and Asian communities were familiar with the concept of functionality of food products and herbs (Valls and others 2013). Nowadays, the advances in scientific research support the idea that diet may fulfill nutritional needs and exert a beneficial role in some diseases (Otles and Cagindi 2012).

Several critical factors have been recognized as the key factors leading to the diffusion of functional foods: health deterioration, due to busy lifestyles, low consumption of convenience foods and insufficient exercise; increased incidence of self-medication; increased awareness of link between diet and health due to information by health authorities and media on nutrition; and a crowded and competitive food market (Granato and others 2010). Above all, the various stakeholders have perceived the economic potential of functional food products as an important part of public health prevention strategies. Some authors reported that an annual reduction of 20% in health-care expenditure is possible through widespread consumption of functional foods (Sun-Waterhouse 2011).

Nowadays, the range of functional foods includes products such as baby foods, baked goods and cereals, dairy foods, confectionery, ready meals, snacks, meat products, spreads, and beverages (Ofori and Hsieh 2013). In particular, beverages are by far the most active functional foods category because of (i) convenience and possibility to meet consumer demands for container contents, size, shape, and appearance; (ii) ease of distribution and better storage for refrigerated and shelf-stable products; (iii) great opportunity to incorporate desirable nutrients and bioactive compounds (Sanguansri and Augustin 2009; Wootton-Beard and Ryan 2011; Kausar and others 2012). The different types of commercially available products could be grouped as follows: (1) dairy-based beverages including probiotics and minerals/ω-3 enriched drinks, (2) vegetable and fruit beverages, and (3) sports and energy drinks.

A number of review articles have focused on the main aspects of overall functional foods (Ozen and others 2012; Bigliardi and Galati 2013; Lau and others 2013), probiotic-based (Prado and others 2008; Granato and others 2010; Özer and Kirmaci 2010), fermented (Marsh and others 2014), and fruit-based beverages (Sun-Waterhouse 2011), as well as energy (Heckman and others 2010; Committee on Nutrition and the Council on Sports Medicine and Fitness 2011) and sport drinks (Committee on Nutrition and the Council on Sports Medicine and Fitness 2011). However, none of the cited reports gives a comprehensive picture of the current achievements of functional beverages. Therefore, after a brief summary on the definitions, regulatory framework,

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and market size of functional foods, a review of the scientific advances on functional beverages is presented, with a focus on the main examples of commercially available products and potential health benefits due to their consumption.

A Window on Functional Foods

Definitions

Historically, various terms have been used interchangeably to designate foods for disease prevention and health promotion. The term *designer foods*, coined in 1989, is used to describe foods that naturally contain or are enriched with nonnutritive, biologically active chemical components of plants that are effective in reducing cancer risk. The word *Nutraceuticals* was introduced also in 1989 by the U.S. Foundation for Innovation in Medicine to refer to "any substance that is a food or a part of a food and provides medical or health benefits, including the prevention and treatment of disease" (Rodriguez and others 2006). On the other hand, the concept of *functional food* was first introduced in Japan in the mid-1980s for foods containing ingredients with functions for health (FOSHU, food for specified health use) (Lau and others 2013). FOSHU is defined by the Japanese Ministry of Health, Labor and Welfare as "foods which are expected to have certain health benefits, and have been licensed to bear a label claiming that a person using them for specified health use may expect to obtain the health use through the consumption thereof" (Bigliardi and Galati 2013).

In the U.S., functional foods are defined as "foods and food components that provide a health benefit beyond basic nutrition" (Serafini and others 2012). In Canada, a functional food is defined as a "food similar in appearance to, or may be, a conventional food that is consumed as part of a usual diet, and is demonstrated to have physiological benefits and/or reduce the risk of chronic disease beyond basic nutritional functions" (Lau and others 2013). In China, "health (functional) food means that a food has special health functions or is able to supply vitamins or minerals. It is suitable for consumption by special groups of people and has the function of regulating human body functions, but it is not used for therapeutic purposes. And it will not cause any harm whether acute or subacute or chronic" (Yang 2008).

In Europe, the interest in functional foods started in the latter half of the 1990s. The European Commission generated an activity called Functional Food Science in Europe (FuFoSE) to explore the concept of functional foods through a science-based approach. As a result, the European Commission stated that "a food product can only be considered functional if together with the basic nutritional impact it has beneficial effects on one or more functions of the human organism thus either improving the general and physical conditions or/and decreasing the risk of the evolution of diseases" (Ozen and others 2012).

Therefore, a functional food can be: an unmodified natural food; a food in which a component has been enhanced through special growing conditions, breeding, or biotechnological means; a food to which a component has been added to provide benefits; a food from which a component has been removed by technological or biotechnological means so that the food provides benefits not otherwise available; a food in which a component has been replaced by an alternative component with favorable properties; a food in which a component has been modified by enzymatic, chemical, or technological means to provide a benefit; a food in which the bioavailability of a component has been modified; or a combination of any of the above (Pravst 2012).

Regulatory framework

In a regulatory sense, functional foods are not clearly classified and defined. Apart from Japan, the term "functional food" is neither defined nor recognized as a distinct product category by any regulatory authority (Brown and Chan 2009). As a result, it is ambiguous whether a new product should be labeled as food, supplement, or drug (Sun-Waterhouse 2011).

On the other hand, the details on the functionality (health or nutritional claims) should fulfill some basic requirements (Binnis and Howlett 2009). In Europe, nutrition and health claims are regulated by EC Regulation 1924/2006 on "Nutrition and health claims made on foods." Namely, a nutrition claim is a claim which suggests or implies that a food has particular beneficial nutritional properties (such as "source of," "free of," "reduced"), whereas health claims are defined as claims that state, suggest, or imply that a relationship exists between a food category, a food, or one of its components and health. This last definition includes: (1) generic health claims related to (a) the role of a nutrient or other substance in growth, development, or function of the body, (b) psychological and behavioral functions, or (c) slimming, weight-control, satiety, or reduction of available energy; (2) health claims referring to the reduction of a risk factor in the development of a disease and related to children's growth (Dolan 2011). In this sense, it has been estimated that, in the European Union, the costs in the flow-chart for the definition of health claims range from €4.51 to €7.65 million, without taking into account clinical trials and other costs necessary to provide scientific data to support applications to European Food Safety Authority (EFSA; Nocella and Kennedy 2012).

In the U.S., there is not a separate category or a set of regulations for functional foods. These products fall under the regulations for conventional foods. They must be safe to be marketed as foods, and the ingredients must be "generally recognized as safe" (GRAS) or approved as food additives (Jackson and Paliyath 2011). Regarding product claims, these can be categorized into 3 categories: (1) health claims, (2) nutrient content claims, and (3) structure/function claims (Hasler 2008).

Ideally, the same product claim for dietary supplement ingredients in the U.S. could be used internationally. However, based on the different manner in which supplement ingredients are regulated in the U.S. and Europe, many claims that are permitted in the U.S. are not in Europe (or vice versa). In general, it is believed that it is more difficult to market products with claims in Europe because of the extensive authorization procedure which consists of different steps involving the national authorities, EFSA and the European Commission (Dolan 2011).

Market

The increase of the market of functional foods has been related to a steadying increase of the number of functional food launches. As reported by Sorenson and Bogue (2009), the global launches of functional products between 2005 and 2009 have more than doubled, from 904 to 1859. Between 2008 and the first half of 2009, the U.S. was the leader in "healthy" product launches (881 products), followed by Japan (314), Italy (325), UK (237), Germany (235), and France (150).

Due to the lack of an internationally accepted definition of functional food, it is very difficult to study the world-wide functional food markets (Ozen 2012; Valls and others 2013). Therefore, many market studies of global sales of functional foods differ in the data, depending on the criteria used for the inclusion of products in the analysis. For example, under a strict definition, the functional food and beverages market had a combined value of $19.4 billion in 2007, whereas with a broader definition, the market is raised to $41.9 billion. In 2011, the global market for a strict definition of functional products as those offering specific health claims was estimated at $24.2 billion (Valls and others 2013). According to Sloan (2012), global functional food/beverage sales are projected to top $130 billion by 2015.

Despite the lack of precision concerning the data of global sales, functional foods have undeniably been reported as the top trend in food industry. Valls and others (2013) reported that in 2008 the market of functional foods ("products bearing a health claim") was the fastest-growing sector, with an expected annual growth of 10% compared to 2% to 3% for the food industry. In particular, the functional beverage market, valued at $25 billion in 2005, is the fastest growing segment within the functional food sector (Marete and others 2011) with an annually growth of 14% in the U.S. between 2002 and 2007 (Kranz and others 2010). To date, functional beverage sales in the U.S. represent about 59% of the total functional food market (Sloan 2012).

Globally, the trends relating functional beverages are more heterogeneous than homogeneous, evolving and growing at different rates both within and across Countries, due to sociodemographic and sociocultural differences in consumer perceptions and acceptance of functional products. For example, while the U.S. probiotic dairy categories have experienced impressive growth rates in recent years, these categories still remain largely underdeveloped in volume and value terms in comparison to the French, German, Spanish, and the UK markets. Similarly, the sport drink category remains largely underdeveloped outside the U.S. and Japan where energy and fortified drinks dominate a number of key European beverage markets (Sorenson and Bogue 2009).

Inside the Commercial Functional Beverages

Dairy-based beverages

Within dairy beverages, fresh milk, fermented milk, and yogurt drinks are the most common products, as they are considered excellent vehicles for probiotics (Gürakan and others 2010). Probiotics are currently defined as "live microorganisms which when administered in adequate amounts confer a health benefit to the host." The health effects attributed to probiotics are diverse. These include: alleviation of lactose-intolerance symptoms, treatment of viral and antibiotic-associated diarrhea, reduction of symptoms of antibiotic treatment of *Helicobacter pylori*, alleviation of atopic dermatitis symptoms in children, and prevention of the risk of allergy in infancy, alleviation of symptoms of inflammable bowel disease (IBD) and irritable bowel syndrome (IBS), and enhancing the immune response (Saarela 2009). Food industries, especially dairy companies, have realized the huge market potential created by the numerous positive health benefits of probiotic bacteria (Talwalkar and Kailasapathy 2004). Therefore, a growing number of dairy manufacturers add *Lactobacillus* spp. and *Bifidobacterium* spp., but not exclusively, to some of their products. The most commonly incorporated probiotic bacteria include *L. acidophilus*, *L. rhamnosus*, and *L. casei* among lactobacilli and *B. bifidum* among bifidobacteria. Table 1 lists some of the commercially available probiotic beverages. Some examples of these products are Actimel® (Danone, France) with *L. casei* Immunitas™, Yakult® (Yakult Honsha Co, Japan) with *L. casei* Shirota, and CHAMYTO® (Nestle, France) with *L. johnsonii* and *L. helveticus*.

On the other hand, there are many commercial dairy beverages enriched with bioactive components, like ω-3 fatty acids (Table 1): α-linoleic acid (C18:3 n-3, ALA), eicosapentaenoic acid (C20:5 n-3, EPA), and docosahexanoic acid (C22:6 n-3, DHA; Özer and Kirmaci 2010). Recently, clinical studies have shown that ω-3 acids may be useful in the prevention and treatment of epilepsy (Boroski and others 2012). Some examples of these products are Natrel Omega-3® (Natrel, Canada) and Heart Plus® (PB Food, Australia).

Food proteins, especially milk caseins, may act as a precursor of biologically active peptides with different physiological effects; these compounds can inhibit the enzyme angiotensin-converting enzyme (ACE-I) playing a major role in converting angiotensin-I to angiotensin-II and degrading brydikinin by blocking the active site of the enzyme. The conversion of angiotensin-I to angiotensin II and the degradation of brydikinin result in increased blood pressure, while the inhibition of the enzyme reduces pressure increase (Özer and Kirmaci 2010). An example of commercial beverage with added bioactive peptides is Evolus® from Valio Ltd. (Finland). Its beneficial effect is due to the bioactive peptides synthetized by *L. helveticus* from milk casein (Prado and others 2008).

Plant sterols (PS; including phytosterols and phytostanols) are a group of steroid alcohols with promising potentialities. According to emerging evidence, the phytosterols have shown potential in reducing cancers of the stomach, lung, ovaries, and breasts (Woyengo and others 2009; Bradford and Awad 2010; Grattan 2013). When added to foods, plant stanols effectively reduce the absorption of all sterols from the digestive tract, hence also decreasing serum cholesterol levels (Özer and Kirmaci 2010). The main source of PS for current functional foods and dietary supplements is tall oil, a by-product of the wood pulp industry, and vegetable oil deodorizer distillate. Thus, the enrichment with PS is a promising way to obtain the daily recommended amount of PS for subjects with moderate hypercholesterolemia (Alemany-Costa and others 2012). Raisio Benecol Ltd. (Finland) holds the trademark of Benecol®, which is the leading brand in the field of plant stanol-containing products.

Conjugated linoleic acid (CLA) has been demonstrated to have anti-oxidative and anticancer effects (Özer and Kirmaci 2010). Natural Linea® (Corporacion Alimentaria Penanata S.A., Spain) is an example of a commercial product with added CLA.

Melatonin is a naturally occurring hormone found in animals and in some other living organisms, including algae. It controls the body's day-and-night rhythm and is effective toward sleeplessness (Özer and Kirmaci 2010). An example of a commercial product with added melatonin is Night-Time Milk® from Cricketer Farm (UK).

Apart from the aforementioned nutraceuticals, vitamins and minerals are also added to dairy beverages to compensate for vitamin and mineral losses during processing (Özer and Kirmaci 2010). Dairyland Milk-2-Go® (Saputo, Canada) is an example of a commercial dairy beverage with added vitamins. As regards minerals, calcium, magnesium, and iron are the most common compounds added to dairy beverages due to their pivotal role in the human organism (Özer and Kirmaci 2010). Some examples of minerals-added products are Meiji Love® (Meiji Milk, Japan) and Zen® (Danone, Belgium).

Vegetable and fruit beverages

Milk has been long considered as the only food containing all different essential substances for human nutrition. However, some researchers have recently focused some constituents, such as vitamin D, proteins, calcium, CLA, butyrate, saturated fatty acids, and contaminants such as pesticides, estrogen, and insulin-like growth factor I (IGF-I), which might be responsible for either a

Table 1–Some examples of commercially available dairy beverages.

Brand	Producer	Active compounds
Probiotics		
Verum®	Essum AB, Sweden	*Lactococcus lactis* L1A, *Lactobacillus rhamnosus* LB21
Gaio®	MD Foods, Denmark	*Enterococus faecium*, *Streptococcus thermophilus*
Actimel®	Danone, France	*L. casei* Immunitas™
Vifit Drink®	Mona, The Netherlands	*L. casei* GG, *L. acidophilus*, *Bifidobacterium bifidum*
CHAMYTO®	Nestle, France	*L. johnsonii*, *L. helveticus*
Yakult®	Yakult Honsha Co, Japan	*L. casei* Shirota
Yakult Miru-Miru®	Yakult Honsha Co, Japan	*L. casei*, *B. bifidum* or *B. breve*, *L. acidophilus*
Cultura®	Arla Foods, Sweden	*L. acidophilus*, *B. bifidum*
Vitagen®	Malaysia Milk SDN. BHD, Malaysia	*L. acidophilus*, *L. casei*
ProCult Drink®	Müller, Germany	*B. longum* BB536, *S. thermophilus*, *L. delbrueckii* subsp. *bulgaricus*
Enriched beverages		
Heart Plus®	PB Food, Australia	Omega-3
Natrel Omega-3®	Natrel, Canada	Omega-3
Night-Time Milk®	Cricketer Farm, UK	Melatonin
Meiji Love®	Meiji Milk, Japan	Calcium and iron
Dairyland Milk-2-Go®	Saputo, Canada	Calcium, omega-3, vitamins
Natural Linea®	Corporacion Alimentaria Penanata S.A., Spain	Conjugated linoleic acid
Benecol®	Mc Neil Nutritionals, UK	Phytosterol
Danacol®	Danone, France	Phytosterol
Zen®	Danone, Belgium	Magnesium
Evolus®	Valio Ltd., Finland	Bioactive peptides

Data from Holzapfel (2006), Gürakan and others (2010), Özer and Kirmaci (2010), Soccol and others (2012), and World Wide Web.

Table 2–Some examples of commercially available vegetable and fruit beverages.

Brand	Producer	Active compounds
Probiotics		
Vita Biosa®	Biola Inc., Canada	Antioxidants; Probiotics: *L. acidophilus*, *L. casei*, *B. bifidum*
Proviva®	Skane Dairy, Sweden	Probiotics: *L. plantarum* 299v
Gefilus®	Valio Ltd., Finland	Vitamins C and D; Probiotics: *L. rhamnosus* GG
Bioprofit®	Valio Ltd., Finland	Probiotics: *L. rhamnosus* GG, *P. freudenreichii* ssp. *shermanii* JS
Biola®	Tine BA, Norway	Probiotics: *L. rhamnosus* GG
Rela®	Arla Ingman Ou Ab., Finland	Probiotics: *L. acidophilus*, *L. reuteri*, *B. lactis*
Whole Grain Probiotic Liquid®	Grainfields, Australia	Vitamins, amino acids, and enzymes; Probiotics: *L. acidophilus*, *L. delbrueckii*, *Saccharomyces cerevisiae* var. *boulardii*, *S. cerevisiae*
Friscus®	Skånemejerier, Sweden	Probiotics: *L. plantarum* HEAL9, *L. paracasei* 8700:2
Silk Live®	WhiteWave Foods, U.S.A.	Probiotics: *L. bulgaricus*, *S. thermophilus*, *L. acidophilus*, *B. bifidum*, *L. casei*, *L. rhamnosus*
Goodbelly®	NextFoods, U.S.A.	Probiotics: *L. plantarum* 299v
Enriched beverages		
Tropicana Essentials Orange Juice & Calcium®	Tropicana, U.S.A.	Calcium
Tropicana Farmstand®	Tropicana, U.S.A.	Vitamins A and C; potassium
Tomato Juice Plus®	Langer Juice Co., Inc., U.S.A.	Vitamins and minerals
L&A Tomato Juice®	Langer Juice Co., Inc., U.S.A.	Vitamins and minerals
Daily Greens®	Bolthouse Farms, U.S.A.	Vitamins A and C; manganese, iron, and zinc
V Blend Vegetable / Fruit Blend®	Country Pure Foods, U.S.A.	Vitamins A, C, and E
Welch's 100% Grape Juice with Calcium®	Welch Foods Inc., U.S.A.	Calcium
Tropicana Pure Premium Calcium Orange Juice®	Tropicana, U.S.A.	Calcium
Minute Maid with Calcium & Vitamin D®	Minute Maid, U.S.A.	Calcium and vitamin D
Oasis Health Break ®	Lassonde Inc., U.S.A.	Omega-3

Data from Gürakan and others (2010), Özer and Kirmaci (2010), Soccol and others (2012), and World Wide Web.

prospective or a harmful association between dairy products and cancers (Davoodi and others 2013). Moreover, lactose intolerance and cholesterol content are major drawbacks related to functional dairy products (Prado and others 2008). Hippocrates first described lactose intolerance 2400 years ago, but the clinical symptoms have become recognized only in the last 50 years. Up to 70% of the world population has lactase nonpersistence, although lactose tolerance could be affected by many nutritional and genetic factors. In Europe, the prevalence of lactose intolerance is about 5% in the British population and has increased to 17% in Finland and northern France (Lomer and others 2008). The prevalence is above 50% in South America, Africa, and Asia, reaching almost 100% in some Asian countries (Zannini and others 2013). In the U.S., the prevalence is 15% among whites, 53% in Mexican- Americans, and 80% in the African-American population. Australia and New Zealand have a prevalence of lactose intolerance of 6% to 9% (Tomar 2014). Indeed, new products containing probiotic strains have been launched, particularly beverages based on fruits, vegetables, cereals, and soybeans (Saarela 2009; Soccol and others 2012). Table 2 shows some examples of these products.

Fruit juices could be ideal media for probiotic due to their content of essential nutrients (Granato and others 2010); some fruits used in commercial preparations include cranberry, blueberry, pomegranate, apple, blackcurrant, acai, acerola, guarana, mango, bilberries, grapes, cherries, kiwifruits, strawberries, feijoa, peach, and plums (Sun-Waterhouse 2011). In addition, juices from watermelon, sapodilla, and orange were tested as suitable carrier for lactobacilli to prepare health beverage for consumers who are allergic to dairy products (Gaanappriya and others 2013).

Examples of available products are Rela® (Biogaia, Sweden), a fruit juice with *L. reuteri* MM53; Gefilus® (Valio Ltd., Finland), a fruit drink with a 5-week shelf-life under refrigeration; Bioprofit® (Valio Ltd.), with *L. rhamnosus* GG and *Propionibacterium freudenreichii* ssp. *shermanii* JS; and Biola® (Tine BA, Norway), a juice drink with more than 95% fruit and no added sugar (Prado and others 2008).

Soybeans are an interesting alternative due to some key elements like the quality of the protein and amino acids, the low cost of production (Molina and others 2012), the contents of fiber, magnesium, phosphorus, vitamin K, riboflavin, thiamine, folic acid, isoflavones, and other flavonoids, compounds with strong antioxidant activity, acting in the prevention of nontransmissible chronic-degenerative diseases such as many types of cancer (Granato and others 2010). Aromatic herbs could also be used as suitable media for lactic acid bacteria (LAB) cultures. An example of a vegetable beverage is Vita Biosa® (Biosa Inc., Canada), a mixture of aromatic herbs and other plants fermented by a combination of LAB cultures (*L. acidophilus* and *L. casei*) and *Bifidobacterium bifidum* (Soccol and others 2012).

In recent years, cereals have been also investigated as fermentable substrates for the growth of probiotic microorganisms (Nyanzi and Jooste 2012). Cereals have a huge potential as vehicles for functional compounds such as antioxidants, dietary fiber, minerals, prebiotics, and vitamins (Nionelli and others 2014). Examples of commercial products are Proviva® (Skane Dairy, Sweden), the first oat-based probiotic food beverage where the active probiotic component is *L. plantarum* 299v (Prado and others 2008); and Whole Grain Probiotic Liquid® (Grainfields, Australia), a refreshing, effervescent liquid containing both LAB (*L. acidophilus*, *L. delbrueckii*) and yeasts (*Saccharomyces cerevisiae* var. *boulardii* and *S. cerevisiae*) as well as vitamins, amino acids, and enzymes (Soccol and others 2012).

Finally, some nonprobiotic fruit and vegetable beverages with added vitamins and minerals (like vitamin D or calcium) are also being marketed. The goal is both an increase of their nutritive value and the prevention of certain diseases like rickets in children and osteomalacia and osteoporosis in adults (Tangpricha and others 2003). Some examples of commercial fruit-based products are Tropicana Essentials® Orange Juice & Calcium (Tropicana, U.S.A.), and Minute Maid® with Calcium & Vitamin D (Minute Maid, U.S.A.); while some vegetable-based beverages include Daily Greens (Bolthouse Farms, U.S.A.), which blends spinach, cucumber, and kale with a hint of lemon; and Langers Tomato Juice Plus and L&A Tomato Juice (Langer Juice Co., Inc., U.S.A.), made of 100% pure tomato juice without added sugar, high-fructose corn syrup, sweeteners, or preservatives.

Sports drinks

Sports drinks are flavored beverages designed to be consumed before or during exercise to prevent dehydration, supply carbohydrates, provide electrolytes (such as sodium, potassium, calcium, magnesium) and, sometimes, vitamins or other nutrients, and they typically do not contain caffeine (Heckman and others 2010; Committee on Nutrition and the Council on Sports Medicine and Fitness 2011). Safety and effectiveness of these products are supported by an extensive literature (Costill 1988; Maughan 1991; Maughan and Noakes 1991; Burke 2001; Maughan 2003; Meyer and others 2013).

Sports drinks can indeed be considered as an optimal tool that boast superiority to water (Higgins and others 2010). For example, cyclists who drank a sodium-containing sports drink during a 3-h ride in warm temperatures maintained plasma sodium levels and had less urine production than those who drank only water (Bunn 2013). Many sports drinks contain a combination of glucose, fructose, sucrose, and maltodextrin/glucose polymers. The addition of maltodextrins and glucose polymers relies upon the fact that they are less sweet than sucrose or glucose and the lower sweetness permits a higher concentration of carbohydrate without making the product too sweet to consume (Campbell 2013). However, excessive regular consumption of carbohydrate-containing sport drinks increases overall daily caloric intake without significant additional nutritional value, dental caries, excess weight gain, and poor diet quality (Committee on Nutrition and the Council on Sports Medicine and Fitness 2011; Larson and others 2014). Some examples of commercially available products are Gatorade® (PepsiCo Inc., U.S.A.), Powerade® (Coca-Cola Co., U.S.A.), and Accelerade® (Pacific Health Laboratories Inc., U.S.A.) (Table 3).

Energy drinks

Energy drinks have become popular beverages among young individuals and marketed to college students, athletes, and active individuals between the ages of 21 and 35 years (Dikici and others 2014). Reports have suggested that 30% of young adults regularly consume energy drinks and more than 40% of athletes use energy drinks to enhance their workouts (Duncan and Hankey 2013). They are labeled as functional beverages by Heckman and others (2010) and their commercial label (energy drinks) refers to the main goal: to provide sustenance and improve performance, concentration, and endurance (Gunja and Brown 2012). Although there are hundreds of energy drinks on the market, many products share very similar ingredient profiles (Heckman and others 2010). The most common ingredient is caffeine, often combined with taurine, glucuronolactone, guarana, and B vitamins to form an "energy blend" (Higgins and others 2010). Some examples of these products are Red Bull® (Red Bull GmbH, Austria), Full Throttle® (Coca-Cola Co., U.S.A.), and Monster Energy® (Hansen Natural Corp., U.S.A.).

Recently, serious concerns have arisen about the safety of these drinks or some of their major components (caffeine, guarana, and ginseng). Namely, caffeine has been shown to enhance physical performance in adults by increasing aerobic endurance and strength, improving reaction time, and delaying fatigue. However, these effects are extremely variable, dose-dependent, and their effects have not been studied in children and adolescents (Committee on Nutrition and the Council on Sports Medicine and Fitness 2011).

Guarana comes from the *Paullinia cupana* plant, indigenous to South America. Xanthine alkaloids, namely theobromine and theophylline, and high amounts of saponins, flavonoids, and tannins, contribute to its bioactive properties including its antioxidant activity. However, guarana contains significant amounts of caffeine (Heckman and others 2010), thus its presence in an energy drink is a cause of concern because it increases the total caffeine level in the beverage (Committee on Nutrition and the Council on Sports Medicine and Fitness 2011). Conversely, guarana increases the amount of caffeine and other active methylxanthines that multiply any potential toxicity (Zeidán-Chuliá and others 2013).

Table 3–Some examples of commercially available sport and energy drinks.

Brand	Producer	Active compounds
Sport drinks		
All Sport Body Quencher®	All Sport. Inc., U.S.A.	Sodium, potassium, vitamin C
All Sport Naturally Zero®	All Sport. Inc., U.S.A.	Sodium, potassium, B-vitamins
Gatorade®	PepsiCo Inc., U.S.A.	Sodium, potassium,
Gatorade Propel®	PepsiCo Inc., U.S.A.	Sodium, B-vitamins, vitamins C and E
Gatorade Endurance®	PepsiCo Inc., U.S.A.	Sodium, potassium, calcium, magnesium
Gatorade G2®	PepsiCo Inc., U.S.A.	Sodium, potassium,
Powerade Zero®	Coca- Cola Co., U.S.A.	Sodium, potassium, B-vitamins
Powerade®	Coca- Cola Co., U.S.A.	Sodium, iron
Powerade Ion4®	Coca- Cola Co., U.S.A.	Sodium, potassium, B-vitamins
Accelerade®	Pacific Health Laboratories Inc., U.S.A.	Sodium, potassium, vitamin E, calcium, protein
Energy drinks		
Java Monster®	Hansen Natural Corp., U.S.A.	Sodium, potassium, caffeine, calcium, B-vitamins and vitamins A, C and D, taurine, guarana, inositol, ginseng, L-carnitine, glucuronolactone, phosphorus
Java Monster Lo-Ball®	Hansen Natural Corp., U.S.A.	Sodium, potassium, caffeine, calcium, B-vitamins and vitamins C and D, inositol, ginseng, L-carnitine, glucuronolactone, phosphorus
Monster Energy®	Hansen Natural Corp., U.S.A.	Sodium, caffeine, B-vitamins and vitamin C, taurine, guarana, inositol, ginseng, L-carnitine, glucuronolactone
Monster Low Carb®	Hansen Natural Corp., U.S.A.	Sodium, caffeine, B-vitamins, taurine, guarana, inositol, ginseng, L-carnitine, glucuronolactone
Red Bull®	Red Bull GmbH, Austria	Sodium, caffeine, B-vitamins, taurine, inositol, glucuronolactone
Red Bull Energy Shot®	Red Bull GmbH, Austria	Caffeine, B-vitamins, taurine, glucuronolactone
Power Trip Original Blue®	Power Trip Beverages Inc., U.S.A.	Sodium, caffeine, B-vitamins and vitamin C, taurine, guarana, inositol, glucuronolactone
Power Trip the Extreme®	Power Trip Beverages Inc., U.S.A.	Sodium, caffeine, B-vitamins and vitamin C, taurine, guarana, inositol, glucuronolactone
Rockstar Original®	Rockstar Inc., U.S.A.	Sodium, caffeine, B-vitamins, taurine, guarana, ginseng, inositol, ginkgo, L-carnitine
Full Throttle®	Coca-Cola Co., U.S.A.	Sodium, caffeine, B-vitamins

Data from Heckman and others (2010), Committee on Nutrition and the Council on Sports Medicine and Fitness (2011), and World Wibe Web.

Ginseng is an herb that has been used for over 2000 years by people in East Asian areas, including China, Japan, and Korea, as a remedy for various diseases and for promoting longevity. There are several reported health benefits of ginseng, including immune system stimulation, improved physical and mental conditions, and antistress, antiaging, antioxidant, and anti-inflammatory properties (Committee on Nutrition and the Council on Sports Medicine and Fitness 2011). However, ginseng has multiple and important drug interactions that could become clinically relevant depending on the ingested amount and the dose and frequency of medications that might interact with it (Gunja and Brown 2012).

Of particular concern is the increasing use of alcohol mixed with energy drinks, which is associated with a number of alcohol-related problems and complications in younger populations. These include an increased likelihood of alcohol dependence, higher rates of binge drinking, and an increase in the likelihood of alcohol-related accidents and injuries (Azagba and others 2014).

Functional Beverages: the State of the Art in Research

Many researchers report that functional foods represent one of the most interesting areas of research and innovation in the food field (Bigliardi and Galati 2013), as suggested by the increasing number of scientific papers dealing with this topic since 2007 (Table 4).

The different approaches could be grouped as follows: (1) exploitation of microorganism functionality, (2) optimization of the production and formulation of novel functional beverages, (3) use of prebiotics and synbiotics, (4) use and processing of natural ingredients, (5) use of by-products of fruit and food industries as functional ingredients. In addition, some papers focus and propose application of novel technologies to improve the production of functional beverages without compromising their sensory and functional properties.

Exploitation of microorganism functionality

Besides the production of lactic acid, LAB also have the ability to contribute to the production of several important nutraceuticals through fermentation (Waters and others 2013). The mechanisms by which LAB fulfill the role of efficient cell factory for the production of functional biomolecules were mainly demonstrated for cereal-based beverages (Nionelli and others 2014). Cereal fermentation leads to the decrease of the level of carbohydrates as well as some nondigestible poly- and oligo-saccharides, while the availability of certain amino acids and B vitamins is improved (Gobbetti and others 2010). Indeed, the selection of appropriate starter cultures for each variant of cereal beverage is an industrial need to drive, accelerate, and standardize the fermentation (Nionelli and others 2014). Conversely, bacterial fermentation can also preserve major phenolic compounds in tea (Zhao and Shah 2014) and organic pomegranate (*Punica granatum* L.) juice (Filannino and others 2013).

An attractive approach to improve the nutritional value of fermented functional foods relies upon the activity of functional bacteria (Gobbetti and others 2010); for example, many LAB and *Bifidobacterium* spp. have been reported to produce vitamins such as folate, cobalamin, menaquinone (vitamin K), riboflavin and thiamine. The use of these cultures in food fermentation potentially provides routes not only to enhance the nutritional profile of the food but also to deliver microorganisms to the gut, where they can synthesise such vitamins *in vivo* (O'Connor and others 2005). A further aspect related to the exploitation of microorganism functionality includes the production of bacterial polysaccharides. Zannini and others (2013) reported on the *in situ* production of oligosaccharides (OS) and exopolysaccharides (EPS) by *Weissella cibaria* MG1; these compounds are emulsifiers or stabilizers and positively affect the texture of cereal-based beverages. For example, Coda and others (2011) observed an increase of viscosity in the texture of functional beverages using a rediscovered ancient

Table 4–Functional beverages: selected publications on the state of the art in research.

Products	Active compounds	References
Fortified-strawberry beverage	Polyphenols (rose petals, *Rosa damascena* Mill.)	Mollov and others (2007)
Fermented carrot juice beverage	Prebiotics: inulin and fructooligosaccharides; Probiotics: *L.rhamnosus* DSM20711, *L. bulgaricus* ATCC 11842	Nazzaro and others (2008)
Fortified fruit juice beverage	Prebiotics: fructooligosaccharides	Renuka and others (2009)
Fiber-fortified dairy beverage	Fibers (soybean)	Chen and others (2010)
Grape-based fermented beverage with potential anti-hypertensive effect	Polyphenols (grape must); γ-amino butyric acid (*L. plantarum* DSM19463)	Di Cagno and others (2010)
Fermented cereal drink	Fibers (oat, *Avena sativa*) Probiotics: *L. plantarum* ATCC 8014	Gupta and others (2010)
Olive leaf extract-enriched fruit beverage	Polyphenols (olive leaf extract)	Kranz and others (2010)
Fermented whey beverage with low lactose and β-lactoglobulin contents and high essential amino acid concentration	Proteins (whey); Lactic acid bacteria: *L. acidophilus* CRL 636, *L. delbrueckii* subsp. *bulgaricus* CRL 656, *S. thermophilus* CRL 804	Pescuma and others (2010)
Antioxidant red-colored beverage	Polyphenols (red-fleshed apples)	Rupasinghe and others (2010)
Cereal-based alcoholic beverage	Exopolysaccharides (*W. cibaria* WC4); Proteins, fibers, vitamins and minerals (emmer grains, *Triticum dicoccum*); Probiotics: *L. rhamnosus* SP1; LAB: *L. plantarum* 6E	Coda and others (2011)
Vegetable health-promoting beverage	Nitrogen–sulfur compounds, phenolics, minerals and vitamins (broccoli, *Brassica oleracea* L. var. *italica*); Favonols and flavanols (green tea extract)	Dominguez-Perles and others (2011)
Peach-flavored yogurt drinks	Prebiotics: fructooligosaccharide; Probiotics: *L. acidophilus* Lafti-L10	Gonzalez and others (2011)
Beverage with anti-inflammatory properties	Phenolic compounds, parthenolide (feverfew, *Tanacetum parthenium*)	Marete and others (2011)
Fermented milk beverage fortified with phenolic compounds	Polyphenols (olive vegetable water); γ-amino butyric acid (*L. plantarum* C48); LAB: *L. paracasei* 15N	Servili and others (2011)
Fruit and milk-based beverages	Plant sterols (tall oil, and soybean, rapeseed, sunflower and corn oils)	Alemany-Costa and others (2012)
Antioxidant dairy-based beverage	Antioxidants (extract of oregano, *Origanum vulgare*; essential oil of oregano, *Origanum minutiflorum*)	Boroski and others (2012)
Vegetable fermented beverage with hypocholesterolemic and hepatoprotective effect	Xanthines, polyphenols and other antioxidants (Herbal mate leaves, *Ilex paraguariensis* A.St.-Hil.); Probiotics: *L. acidophilus* ATCC 4356	Lima and others (2012)
Vegetable drink	Favonoids (Maqui berry, *Aristotelia chilensis*) and vitamin C (lemon juice)	Gironés-Vilaplana and others (2012)
Antioxidant beverage	Polyphenols (red grape, *Vitis vinifera* L.; elderberry, *Sambucus nigra* L.)	González-Molina and others (2012)
Blended drink	Fibers, vitamins and minerals (cucumber, *Cucumis sativus* and muskmelon, *Cucumis melo*)	Kausar and others (2012)
Fermented cereal-based probiotic drink	Proteins, fibers, vitamins, and minerals (malt, barley); Probiotics: *L. plantarum* NCIMB 8826, *L. acidophilus* NCIMB 8821	Rathore and others (2012)
Fortified blackcurrant juice	Polyphenols (crowberry, *Empetrum nigrum*)	Törrönen and others (2012)
Antioxidant blended-beverage	Antioxidants (cocoa, *Theobroma cacao*; *Hibiscus*-flower-extract; ginger, *Zingiber officinale*)	Awe and others (2013)
Whey-based prickly pear beverage	Minerals, proteins, free amino acids (prickly pear fruit of *Opuntia* spp.)	Baccouche and others (2013)
Fermented sprouts buckwheat beverage	Antioxidants (buckwheat, *Fagopyrum esculentum* Moench) Probiotics: *L. plantarum* Prebiotics: inulin	Brajdes and Vizireanu (2013)
Fortified vegetable-beverage	Vitamins, minerals, polyphenols omega-3 fatty acids, proteins, digestible carbohydrates (whey, mango fruit)	Gad and others (2013)
Cardio-protective fruit-based beverage	Ginger, amino acids, vitamins and minerals (available commercial products)	Gunathilake and others (2013a)

(*Continued*)

Table 4–Continued.

Products	Active compounds	References
Fruit-based beverage with hypolipidaemic effects	Ginger, amino acids, vitamins and minerals (available commercial products)	Gunathilake and others (2013b)
Fortified fruit juice	Antioxidants (brewers' spent grain)	McCarthy and others (2013)
Enriched fruit juice	L-citrulline (available commercial product)	Tarazona-Díaz and others (2013)
Natural, minimally processed plant-derived beverage	Antioxidants, phenolic compounds (sugar and red maple, *Acer saccharum* and *Acer rubrum*)	Yuan and others (2013)
Alcohol-free beverage	Oligosaccharides and exopolysaccharides (*W. cibaria* MG1)	Zannini and others (2013)
Beverage for reducing body fat accumulation	Antioxidants (coffee silverskin extract)	Martinez-Saez and others (2014)
Fermented beverage for cardiovascular protection	Phenolic compounds (Jabuticaba berry, *Myrciaria jaboticaba*)	Martins de Sá and others (2014)
Fermented yougurt-like beverage	β-Glucans (oat flakes); Lactic acid bacteria: *L. plantarum* LP09	Nionelli and others (2014)
Pomegranate fermented juice	Phenolic compounds (pomegranate, *Punica granatum* L.); *S. cerevisiae* Fermicru VR5 and acetic acid bacteria	Ordoudi and others (2014)
Enriched fruit juice-based beverage to attenuate blood glucose and insulin responses	Xanthan gum, barley β-glucan, guar gum, and konjac-mannan (available commercial products)	Paquet and others (2014)
Vegetable and fermented vegetable juices for cardiovascular diseases,type II diabetes, and obesity	Antioxidants (vegetables, seeds and sprouts of germinated lentils and cowpeas); Lactic acid bacteria: *L. plantarum* VISBYVAC	Simsek and others (2014)
Apple-based beverage with anti-diabetic properties	Secoiridoid glycosides (*Fraxinus excelsior* seed extract)	Varela and others (2014)
Carbonated symbiotic milk-based beverage	Probiotics: *L. acidophilus* and *Bifidobacterium* spp. Prebiotics: inulin	Walsh and others (2014)
Fermented soymilk-tea beverage	Polyphenols (tea), isoflavones (soy); Lactic acid bacteria and *Bifidobacterium* spp.: *S. thermophilus* ASCC 1275, *L. delbrueckii* ssp. *bulgaricus* ASCC 859 and *B. longum* CSCC 5089	Zhao and Shah (2014)
Peanut soy milk	Proteins (Peanut, soy); Probiotics: *L. rhamnosus* LR 32, *L. acidophilus* LACA 4; Lactic acid bacteria: *P. acidilactici* UFLA BFFCX 27.1, *L. delbrueckii* subsp. *bulgaricus* LB 340, *L. lactis* CCT 0360; *S. cerevisiae* UFLA YFFBM 18.03	Santos and others (2014)
Fermented pepper leaves-based beverage	Antioxidants, phenolic compounds (pepper, *Capsicum annuum* L.); Lactic acid bacteria: *L. homohiochii* JBCC 25 and JBCC 46	Song and others (2014)

grain (emmer) by an EPS-producing strain of *W. cibaria* WC4. This aspect is of concern also due to the fact that both EPS and OS act as stress protectants against the bactericidal effects of bile salts (Yeo and others 2011).

Di Cagno and others (2010) formulated a health-oriented beverage using grape must supplemented with γ-aminobutyric acid (GABA) through fermentation by *L. plantarum* DSM19463. GABA is a ubiquitous nonprotein amino acid synthesized primarily by α-decarboxylation of glutamate through glutamate decarboxylase (GAD) activity (Servili and others 2011). Some important physiological functions of GABA are neurotransmission, induction of hypotension, diuretic, and tranquilizer effects, and stimulation of immune cells (Di Cagno and others 2010).

Food functionality can also be enhanced using probiotics. The most important traits for a promising probiotic rely upon (a) survival at low pH and with bile salts added; (b) adhesion to intestinal epithelium; (c) antimicrobial activity toward foodborne pathogens and competitive adhesion to mucosa; (d) immumodulation; (e) safety issues (production of harmful metabolites, like biogenic amines, and transmission of genes encoding antibiotic resistance; Sip and Grajek 2009; Nagpal and others 2012). Apart from this classical properties, some additional features are required in functional beverages, like the interaction with the starter cultures, as antagonistic interaction between probiotics and starter cultures may result in growth inhibition by acid, peroxide, bacteriocins, and other metabolites. As a result, the selection of compatible probiotics and starter cultures could be pivotal to prevent inhibition (Nagpal and others 2012; Brajdes and Vizireanu 2013). Similarly, the ability of probiotics to grow well in cereal or fruit and vegetable juices could depend, respectively, on their ability to exhibit amylolytic activity or to resist preservatives (Yeo and others 2011).

Unfortunately, only a few probiotic cultures isolated from human or animal sources and used in dairy products exhibit acceptable adaptation to plant matrices (Peres and others 2014). Thus, the successful "probiotication" of beetroot, carrot, grape, cabbage, apple, orange, tomato, beta, and blackcurrant juices has been recently reviewed by Gobbetti and others (2010).

Due to the fact that the prolongation of shelf-life is a great challenge for functional beverages, some researchers have tried to improve the viability of probiotics. It should be maintained in the food product until the time of consumption and be present in significant numbers, at levels of at least 10^7 viable cells *per* gram or milliliter. Many approaches have been proposed, like a modification of the atmosphere of the product based on the increase of the content of CO_2 in the head space, which might have an impact on the survival of microaerophilic and anaerobic bacteria (Walsh and others 2014). On the other hand, addition of ascorbic acid (vitamin C) might also have a protective effect on probiotic cells during storage, presumably because it is an oxygen scavenger, thus promoting a more favorable anaerobic environment (Shah and others 2010).

Improved viability of probiotics could be achieved upon exposure to sublethal stresses (for example, acid, bile, oxygen, or heat), which might induce the resistance and an adaptive stress response of probiotic cells, thus enhancing the survival in the otherwise lethal conditions encountered during industrial processing and gastrointestinal transit (Gobbetti and others 2010).

Many papers on the probiotication of beverages focused on the use of bacteria (lactobacilli and bifidobacteria). A health-related role for yeasts in functional beverages has not yet elucidated, although they play a major role in the production of many traditional fermented foods and beverages across the world (Aidoo and Nout 2010). Marsh and others (2014) reported on the positive effect of yeasts on the abundance of *Lactobacillus* spp. in fermented environments. Yeast fermentation enhances flavor by increasing production of volatiles such as alcohols, esters, and organic acids diacetyl (Mukisa and others 2012). Recently, Santos and others (2014) evaluated the potential of probiotic *L. acidophilus* (LACA 4) in mixed cultures with *Saccharomyces cerevisiae* (UFLA YFFBM 18.03) for the production of a functional peanut-soy beverage (PSM); as result, yeast did not completely consume the available sugars PSM and consequently produced low amounts of ethanol (0.24 g/L), thus classifying the final beverage as nonalcoholic.

Finally, an innovative aspect related to the exploitation of microorganisms functionality include the functionalization of foods and beverages through the use of active compounds (i.e., EPS; polyunsaturated fatty acids, PUFA; protein and bioactive peptide; probiotics) provided by marine microorganisms (Marsh and others 2014); however, there are a number of legal barriers to be addressed, especially microbial metabolites should come from strains that have been recognized as safe (Dewapriya and Kim 2013).

Optimization of the production and formulation of novel functional beverages

Some examples of novel functional beverages are whey-based prickly pear (Baccouche and others 2013) and grape-based beverages (Di Cagno and others 2010), cereal-based probiotic drink (Rathore and others 2012), fruit-beverages (Gad and others 2013; Gunathilake and others 2013a, 2013b), and some vegetable beverages (Gironés-Vilaplana and others 2012; Awe and others 2013).

A critical topic is the study of the interactions that might occur when some ingredients are mixed together, as their functionality may be lost or reduced by reactions leading to precipitate formation, oxidation, insolubility, or degradation (Sun-Waterhouse 2011; Padilla-Zakour and others 2012). For example, it has been observed that milk affects the flavonoid metabolism pathways by increasing sulfation in healthy subjects (Rodríguez-Roque and others 2014). Thus, it is important to define the "optimal dosage" of each compound, namely the content high enough to exert health benefits, without hazardous effects or undesirable interactions with other functional foods or nutraceuticals (Jackson and Paliyath 2011). Moreover, it is important to define the bioaccessibility (the fraction of bioactive substance that is released from the food matrix after digestion and solubilized into the gut for the uptake in the intestinal mucosa) and bioavailability (the fraction of nutrient secreted into circulation that is available for tissue uptake and metabolism) of bioactive compounds to effectively improve beverage functionality (Rodríguez-Roque and others 2014).

The application of novel technologies could make possible the production of improved functional beverages (Ofori and Hsieh 2013). For example, many dairy products contains active ingredients like soluble fiber, but some compounds of this group could have deleterious effects on texture; in this sense 2 approaches could be used: searching for low-viscosity and nutritionally relevant fiber sources (Chen and others 2010), or adding specific hydrocolloids (Paquet and others 2014) or enzymes (Nionelli and others 2014). Paquet and others (2014) proposed the latter approach for fruit juices enriched with β-glucan. These products could experience a significant decrease in viscosity during heat processing (pasteurization), while juices supplemented with a mixture of β-glucan and xanthan gum remain stable and effectively would reduce the human glycemic response. Moreover, Nionelli and others (2014) reported the prospect of 2 enzyme preparations containing xylanase, endoglucanase, β-glucanase, and ferulic acid esterase (Depol 740L), and α-amylase (Grindamyl) activities to improve the technology and nutritional features of cereal matrices having a high content of fibers.

The supplementation of probiotics to cereal-based matrices may also require special technologies because of the acidic conditions. A possible approach is micro-encapsulation (ME), successfully applied using various matrices to protect the bacterial cells from the external environment (Granato and others 2010). For instance, an increased viability was reported by using the ME of *L. acidophilus* in nanofibers spun from alkali-treated soluble dietary fiber produced from the agro-waste okara (soybean solid waste), oil palm trunk, or oil palm frond (Ofori and Hsieh 2013). Similarly, the encapsulation in alginate–inulin–xanthan prebiotic gum significantly enhanced cell viability of *L. acidophilus* DSM 20079 (Nazzaro and others 2009).

The problems associated with the addition of probiotic cultures to some fruit juices may be overcome by adding small amounts of other juices. For example, when *Lactobacillus* strains are added to fruit juices containing citric acid in orange juice and malic acid in apple juice, the bacteria metabolize these acids and produce CO_2, acetic acid, and lactic acid. The addition of 5% acerola juice to orange juice showed no gas production after 3 weeks and did not show a significant impact on *L. plantarum* HEAL9 and *L. paracasei* 8700:2 cell counts during 4 weeks of storage at 8 °C (Gawkoski and Chikindas 2013).

Use of prebiotics and synbiotics

Some research has been carried out on the fortification of functional beverages with prebiotics. Prebiotics were defined as nondigestible food ingredients that beneficially affect the host by selectively stimulating the growth or activity of one or a limited number of bacterial species residing in the colon, and thus they improve host health. An intake of prebiotics can modulate the gut microbiota by increasing the number of specific bacteria and thereby changing its composition (Pravst 2012).

Nowadays, it is generally accepted that a prebiotic should posses 4 main features:

(1) It should be neither hydrolyzed nor adsorbed in the upper part of the gastrointestinal tract.
(2) It should be a selective substrate for one or more potentially beneficial commensal bacteria in the large intestine. Colonization by an exogenous probiotic could be enhanced and extended by simultaneous administration of a prebiotic; as such it should stimulate bacteria to divide, become metabolically active, or both.
(3) It should alter the colonic microenvironment toward a beneficial composition.
(4) It should induce luminal or systemic effects that are advantageous to the host (Manning and Gibson 2004; Holzapfel 2006; Guo 2009; Sip and Grajek 2009).

Some compounds, like lactulose and lactitol, fructooligosaccharides (FOS), inulin, galactooligosaccharides, and oligosaccharides from soy and levan are listed as prebiotics (Manning and Gibson 2004).

Soluble fibers such as FOS, β-glucan, and inulin have successfully been added to functional beverages. The beneficial physiological effect of soluble dietary fibers seems to be closely related to an increase in the viscosity of gastrointestinal tract's contents that, in turn, reduces the rate of gastric emptying and nutrient absorption by profusely increasing the unstirred layer in the small intestine (Paquet and others 2014). Therefore, the addition of dietary fiber into a diet through the use of functional beverages is a challenge of great concern in the area of nutritional deficiencies. For instance, people from North America consume only about half of the recommended daily amount of dietary fiber which should be 38 g/d for men and 25 g/d for women (Chen and others 2010).

FOS have gained special attention due to their health properties and sweet taste, which is very similar to that of sucrose. FOS exhibit specific physiological effects such as growth stimulation of *Bifidobacterium* spp. in the digestive tract, decreases in total cholesterol and serum lipids, relief from constipation, and general improvement of human health (Renuka and others 2009). Positive effects due to FOS addition were also reported by Gonzalez and others (2011) for peach-flavored drinkable yogurts.

The design of synbiotic products (the combination of probiotics and prebiotics) is the new challenge for functional beverages, as prebiotics could enhance and/or improve the viability of probiotic bacteria and actively stimulate the beneficial microbiota in the gut (Sip and Grajek 2009). Nazzaro and others (2008) designed a functional fermented carrot juice beverage with *L. rhamnosus* DSM 20711 and *L. bulgaricus* ATCC 11842 supplemented with inulin and FOS. Renuka and others (2009) reported that fruit juice beverages could be successfully fortified with FOS with a shelf-life of 4 and 6 mo at ambient temperature and under refrigeration, respectively, without undesirable changes in their physicochemical characteristics. Moreover, Brajdes and Vizireanu (2013) reported that inulin induced better stress resistance in *L. plantarum*, as compared to glucose, whereas the adhesion of probiotics to the surface of enterocytes and of mucosal cells through self-assembly and co-aggregation is about 10 times higher.

Use and processing of natural ingredients

Nowadays an increasing trend in western society is green consumerism, that is consumer interest and focus toward natural and organic products, where the use of synthetic additives is limited. Thus, natural compounds with antimicrobial activity might represent an alternative to fungicides and chemical preservatives; some examples of natural antimicrobials are: (i) oligosaccharides; (ii) plant cell wall polysaccharides as chitosan and oligogalacturonides; (iii) essential oils and plant extracts including rosemary, peppermint, bay, basil, tea tree, celery seed and fennel; and (iv) bacteriocins (Oro 2013). In addition, the increasing interest toward natural antimicrobials relies upon their health benefits (Barbosa-Pereira and others 2013). For example, phenols and carotenoids from fruit by-products could be applied as natural food or beverage preservatives since they extend the shelf-life of the product by delaying the formation of off-flavors and rancidity; moreover, they show well-known health benefits (Galanakis 2012).

It has been suggested that natural ingredients with strong antioxidant activity could be used to design novel functional beverages (Sun-Waterhouse 2011). A possible approach relies upon the fortification with polyphenols as they have gained increasing interest due to their beneficial role against certain cancers, cardiovascular diseases, type 2 diabetes, obesity, and age-related macular degeneration (Servili and others 2011; Törrönen and others 2012). However, many of the potential health-promoting properties may be independent from the antioxidant activity, and polyphenols may directly or indirectly exert their health benefits by interacting with key signal transduction pathways relevant to disease processes (Törrönen and others 2012).

About 1000 compounds having the polyphenol structure, with hydroxyl groups within aromatic rings, have been identified in higher plants and about 100 polyphenols in edible plants (Servili and others 2011). The more common ones are the non-vitamin A carotenoids (lutein and lycopene) and certain groups of plant polyphenols, such as the anthocyanidins and procyanidins (Ottaway 2009). Some interesting sources of phenolics are cocoa, *Hibiscus* flower extract, and ginger (*Zingiber officinale*), and also fruits such as apple, blueberry, and cranberry (Gunathilake and others 2013a). In addition, the potential of some medicinal plants has been investigated. For instance, feverfew (*Tanacetum parthenium*) has been used as a source of nutraceuticals in the manufacture of a functional beverage with anti-inflammatory properties (Marete and others 2011).

As reported for prebiotics, the combination of phenols with probiotic microorganisms represent an innovative biotechnology to enlarge the market for functional beverages (Servili and others 2011; Zhao and Shah 2014). Lima and others (2012) proposed a functional beverage fermented by *L. acidophilus* ATCC 4356 with added herbal mate extract (*Ilex paraguariensis* A.St.-Hil.) for its hypocholesterolemic and hepatoprotective effects.

Unfortunately, the addition of botanical extracts to functional beverages could pose certain problems. First, herbal supplements may have harmful side effects in some cases (high blood pressure, thyroid dysfunction, psychiatric disorders, Parkinson's disease, blood clotting problems, diabetes, heart disease, epilepsy, glaucoma, and a history of stroke) (Jackson and Paliyath 2011). Moreover, it is important to examine the impact of natural ingredients on sensory properties and consumer acceptance (Boroski and others 2012), as well as whether daily intake of such functional beverages with high polyphenol content will influence the desired balance of intestinal microorganisms (Zhao and Shah 2014). On the other hand, many botanical extracts have antioxidant properties, making them sensitive to the presence of oxygen during storage or during manufacturing process (Gruenwald 2009); in this case, nonthermal processing techniques and reverse osmosis can show new ways of producing shelf-stable fruit and vegetable products while preserving their antioxidant properties (Gunathilake and others 2013a; Ofori and Hsieh 2013). A different approach was proposed by González-Molina and others (2012) as they added red fruit concentrates to lemon juice to protect vitamin C, keeping beneficial product properties throughout shelf-life. However, Martí and others (2002) found that the addition of vitamin C to pomegranate juice had no additional benefit, since ascorbic acid degradation was very rapid; a possible solution to overcome this problem could be a blanching treatment, able to inactivate ascorbic acid oxidase (Leong and Oey 2012).

Use of fruit and food industry by-products as functional ingredients

A promising future could be the use of by-products as a source of active ingredients to produce functional beverages. Food processing wastes have long been considered as a matter of treatment, minimization, and prevention due to the environmental effects induced by their disposal (Galanakis 2012). Nowadays, the urgent demands for sustainability in the food and agricultural sectors led to their valorization as a source of bioactive compounds (Galanakis 2013).

One approach was proposed by Servili and others (2011) and consisted in the recovery of bioactive phenols from by-products of virgin olive oil processing and their addition to milk beverages. According to the authors, the phenolic compounds did not affect the fermentation or the metabolism and survival of LAB.

In the production of plum juice or plum pulp, the skins are a waste containing large amounts of polyphenols, which could be recovered for the production of beverages with enhanced polyphenol content and antioxidant capacity. In an industrial setting, the plum skin extract could be concentrated or dried to provide a functional ingredient, not only for plum nectars but also for other functional beverages such as fruit juice-based beverages and flavored iced teas (De Beer and others 2012). However, a drawback might be related to the increase of astringency or bitter taste, which could have a negative effect on the acceptability of the beverages. A solution could be the addition of sweet substances and salts, leading to reduced bitterness perception and to a change in the sensory profile and the nutritional value (Kranz and others 2010).

The recovery of rose petal by-products, rich in polyphenols, was proposed by Mollov and others (2007) to improve the quality of color-labile fruit juices. According to these authors, beverage fortification with phenolic copigments extracted from distilled rose petals was easily applicable at the industrial-scale level. Broccoli by-products were proposed by Dominguez-Perles and others (2011) to provide functional ingredients, thus adding value to food products and reducing agricultural wastes. In particular, the glucosinolates (such as glucoiberin, glucoraphanin, glucoalyssin, glucobrassicin, and neoglucobrassicin) are the health-promoting compounds with antioxidant effects.

Pomegranate seeds represent the by-product of juice and concentrate manufacture. They contain high amounts of interesting compounds, like unsaturated fatty acids and phenolics, thus the seeds can have some beneficial applications in the functional beverage industry, apart from their use as animal feed or in commercial cosmetic products (Mohagheghi and others 2011). In addition, there is a significant overproduction of lemon fruits in some countries and new uses for lemon fruits should be proposed, hence new alternatives for beverage manufacture might result in a promising use of surplus production (González-Molina and others 2012).

Regarding by-products from the food and beverage industries, 2 examples are whey and brewers' spent grain (BSG). Whey is a by-product when making cheese, containing water (93%) and almost 50% of the total solids present in the original milk, mainly lactose (Özer and Kirmaci 2010). A possible application consists in the production of whey-based fruit beverages. For example, Gad and others (2013) proposed the enrichment of whey beverages with mango fruit as a source of vitamins and other phytonutrients, such as antioxidant pigments (carotenoids, such as the provitamin A compound, β-carotene, lutein, and α-carotene). These beverages are extremely calorie dense and could be useful in areas where food insufficiency is problematic (Baccouche and others 2013). They could also provide beneficial effects to people suffering from gastrointestinal disorders (Shiby and Mishra 2013).

Finally, it is possible that BSG, a low-value co-product of the brewing industry, may be used in the production of novel functional beverages, also considering antioxidant health benefits similar to those exhibited by barley (McCarthy and others 2013).

Use of novel technologies

Some papers focus on the application of emerging technologies such as high-pressure processing (HPP), pulsed electric fields (PEF), and nanotechnology to improve the production of functional foods without compromising their sensory and functional properties (Ofori and Hsieh 2013). Cao and others (2011) and Patras and others (2009) found that HPP resulted in a higher retention of antioxidant components (for example, ascorbic acid, anthocyanins, and phenols), and hence higher antioxidant activity for HPP-treated fruits and vegetables. Similar results might be achieved by using PEF in fruit and vegetable processing to preserve vitamin C (Ofori and Hsieh 2013). A great challenge is nanotechnology as an effective way to deliver nano-sized or nano encapsulated nutrients and bioactive compounds and/or release them at controlled rates to sites within the body where they are needed (Wang and Bohn 2012; Ofori and Hsieh 2013). Other emerging technologies are pressurized liquid extraction, subcritical and supercritical extractions, and microwave- and ultrasound-assisted extractions as tools to improve the recovery of bioactive compounds from natural sources, instead of conventional liquid–liquid or solid–liquid extraction (Gil-Chávez and others 2013). However, safety assessment flavor and taste impact as well as consumer acceptance are the challenges that should be addressed before an application of these approaches at industrial level (Galanakis 2013).

Finally, the detection of physiological effects induced in the human body by the uptake of nutrients requires robust technologies to measure many parameters. New "omics" technologies including transcriptomics, proteomics, and metabolomics offer exciting opportunities to address complex issues related to human health, disease, and nutrition (Zhang and others 2010). Metabolomics has been proposed as a tool to achieve molecular fingerprint of fermented foods (soy, cheese, and wine) and is a promising approach for a rapid evaluation of many metabolites and to assess the quality, traceability, and safety of functional beverages (Mozzi and others 2013).

Future Perspectives and Opportunities

Based on consumer demand and the potential of innovation and aforementioned health benefits, we believe that new functional beverages will be launched. The keys to design a second generation of functional beverages could be: (1) the identification and quantification of promising bioactive compounds, (2) the standardization of bioactive compounds, (3) the selection of starters able to produce bioactive compounds, (4) the application of natural biopreservatives to improve the image of naturalness of the functional beverages, (5) the development and validation of standard methods to enhance and ensure the levels of selected phytochemicals and other biologically active compounds in raw and processed products, (6) the establishment of proper dosage and delivery systems, (7) the investigation of bioavailability and metabolism of functional ingredients, (8) the study of safety aspects related to functional beverage consumption, (9) the formulation of value-added products based on traditional fermented beverages, (10) the examination of regulatory issues, (11) the research on the effects of processing on the functional ingredients, (12) the stability of the products, and (13) the potential interactions of the functional ingredients with prescription and nonprescription drugs and with other classes of ingredients.

The future of functional beverages depends on the unequivocal demonstration of their efficacy in promoting health. Thus, a joint venture between food producers and researchers is advisable, as a tool to provide scientific evidence of many health claims, as well as a way to find successful strategies to improve the appeal of functional beverages.

Author Contributions

Each author focused on a topic, performed an accurate search of papers, and wrote the relevant section.

References

Aidoo KE, Nout MJR. 2010. Functional yeasts and molds in fermented foods and beverages. In: Tamang JP, Kailasapathy K, editors. Fermented foods and beverages of the World. Boca Raton, Fla.: Taylor and Francis. p. 127–48.

Alemany-Costa L, González-Larena M, García-Llatas G, Alegría A, Barberá R, Sánchez-Siles LM, Lagarda MJ. 2012. Sterol stability in functional fruit beverages enriched with different plant sterol sources. Food Res Int 48:265–70.

Awe FB, Fagbemi TN, Ifesan BOT, Badejo AA. 2013. Antioxidant properties of cold and hot water extracts of cocoa, *Hibiscus* flower extract, and ginger beverage blends. Food Res Int 52:490–5.

Azagba S, Langille D, Asbridge M. 2014. An emerging adolescent health risk: caffeinated energy drink consumption patterns among high school students. Prev Med 62:54–9.

Baccouche A, Ennouri M, Felfoul I, Attia H. 2013. A physical stability study of whey-based prickly pear beverages. Food Hydrocolloids 33:234–44.

Barbosa-Pereira L, Pocheville A, Angulo I, Paseiro-Losada P, Cruz JM. 2013. Fractionation and purification of bioactive compounds obtained from a brewery waste stream. BioMed Res Int 2013:408491.

Bigliardi B, Galati F. 2013. Innovation trends in the food industry: the case of functional foods. Trends Food Sci Technol 31:118–29.

Binnis N, Howlett J. 2009. Functional foods in Europe: international developments in science and health claims. Eur J Nutr 48:S3–13.

Boroski M, Giroux HJ, Sabik H, Petit HV, Visentainer JV, Matumoto-Pintro PT, Britten M. 2012. Use of oregano extract and oregano essential oil as antioxidants in functional dairy beverage formulations. Food Sci Technol 47:167–74.

Bradford PG, Awad AB. 2010. Modulation of signal transduction in cancer cells by phytosterols. Biofactors 36:241–7.

Brajdes C, Vizireanu C. 2013. Stability of *Lactobacillus plantarum* from functional beverage-based sprouted buckwheat in the conditions simulating in the upper gastrointestinal tract. Glob Res Anal 2:7–8.

Brown PN, Chan M. 2009. An overview of functional food regulation in North America, European Union, Japan and Australia. In: Smith J, Charter E, editors. Functional food product development. New York, N.Y.: John Wiley & Sons. p. 257–92.

Bunn J. 2013. Hydration and performance. In: Campbell B, editor. Sports nutrition—enhancing athletic performance. Florence, S.C.: Taylor & Francis Group. p. 269–96.

Burke LM. 2001. Nutritional needs for exercise in the heat. Comp Biochem Physiol Part A 128:735–48.

Campbell B. 2013. Dietary carbohydrate strategies for performance enhancement. In: Campbell B. editor. Sports nutrition–enhancing athletic performance. Florence, S.C.: Taylor & Francis Group, p. 75–124.

Cao X, Zhang Y, Zhang F, Wang Y, Yi J, Liao X. 2011. Effects of high hydrostatic pressure on enzymes, phenolic compounds, anthocyanins, polymeric color and color of strawberry pulps. J Sci Food Agric 91: 877–85.

Chen W, Duizer L, Corredig M, Goff HD. 2010. Addition of soluble soybean polysaccharides to dairy products as a source of dietary fiber. J Food Sci 75:C478–84.

Coda R, Rizzello CG, Trani A, Gobbetti M. 2011. Manufacture and characterization of functional emmer beverages fermented by selected lactic acid bacteria. Food Microbiol 28:526–36.

Committee on Nutrition and the Council on Sports Medicine and Fitness. 2011. Clinical report—sport drinks and energy drinks for children and adolescents: are they appropriate? Pediatrics 127:1182–9.

Costill DL. 1988. Carbohydrates for exercise:dietary demands for optomal performance. Int J Sport Med 9:1–18.

Davoodi H, Esmaeili S, Mortazavian AM. 2013. Effects of milk and milk products consumption on cancer: a review. Compr Rev Food Sci Food Saf 12:249–64.

De Beer D, Steyn N, Joubert E, Muller N. 2012. Enhancing the polyphenol content of a red-fleshed Japanese plum (*Prunus salicina* Lindl.) nectar by incorporating a polyphenol-rich extract from the skins. J Sci Food Agric 92:2741–50.

Dewapriya P, Kim S. 2013. Marine microorganisms: an emerging avenue in modern nutraceuticals and functional foods. Food Res Int 56:115–25.

Di Cagno R, Mazzacane F, Rizzello CG, De Angelis M, Giuliani G, Meloni M, De Servi B, Gobbetti M. 2010. Synthesis of γ-aminobutyric acid (GABA) by *Lactobacillus plantarum* DSM19463: functional grape must beverage and dermatological applications. Appl Microbiol Biotechnol 86:731–41.

Dikici S, Saritas A, Kilinc S, Guneysu S, Gunes H. 2014. Does an energy drink cause a transient ischemic attack? Am J Emerg Med, in press.

Dolan LC. 2011. Claims: the United States and European perspective. Agro FOOD Indusrty Hi Tech 22:5–7.

Dominguez-Perles R, Moreno DA, Carvajal M, Garcia-Viguera C. 2011. Composition and antioxidant capacity of a novel beverage produced with green tea and minimally-processed by products of broccoli. Innov Food Sci Emerg Technol 12:361–8.

Duncan MJ, Hankey J. 2013. The effect of a caffeinated energy drink on various psychological measures during submaximal cycling. Physiol Behav 116–117:60–5.

Eussen SR, Verhagen H, Klungel OH, Garssen J, van Loveren H, van Kranen HJ, Rompelberg CJ. 2011. Functional foods and dietary supplements: products at the interface between pharma and nutrition. Eur J Pharmacol 668:S2–9.

Filannino P, Azzi L, Cavoski I, Vincentini O, Rizzello CG, Gobbetti M, Di Cagno R. 2013. Exploitation of the health-promoting and sensory properties of organic pomegranate (*Punica granatum* L.) juice through lactic acid fermentation. Int J Food Microbiol 163:184–92.

Gaanappriya M, Guhankumar P, Kiruththica V, Santhiya N, Anita S. 2013. Probiotication of fruit juices by *Lactobacillus acidophilus*. Int J Adv Biotechnol Res 4:72–7.

Gad AS, Emam WH, Mohamed GF, Sayd AF. 2013. Utilization whey in production of functional healthy beverage "whey-mango beverages". Am J Food Technol 8:133–48.

Galanakis CM. 2012. Recovery of high added-value components from food wastes: conventional, emerging technologies and commercialized applications. Trend Food Sci Technol 26:68–87.

Galanakis C.M. 2013. Emerging technologies for the production of nutraceuticals from agricultural by-products: a viewpoint of opportunities and challenges. Food Bioprod Proces 91:575–9.

Gawkoski D, Chikindas ML. 2013. Non-dairy probiotic beverages: the next step into human health. Benef Microb 4:127–42.

Gil-Chávez GJ, Villa JA, Ayala-Zavala JF, Heredia JB, Sepulveda D, Yahia EM, González-Aguilar GA. 2013. Technologies for extraction and production of bioactive compounds to be used as nutraceuticals and food ingredients: an overview. Compr Rev Food Sci Food Saf 12:5–23.

Gironés-Vilaplana A, Mena P, García-Viguera C, Moreno DA. 2012. A novel beverage rich in antioxidant phenolics: Maqui berry (*Aristotelia chilensis*) and lemon juice. Food Sci Technol 47:279–86.

Gobbetti M, Di Cagno R, De Angelis M. 2010. Functional microorganisms for functional food quality. Crit Rev Food Sci Nutr 50:716–27.

Gonzalez NJ, Adhikari K, Sancho-Madriz MF. 2011. Sensory characteristics of peach-flavored yogurt drinks containing prebiotics and synbiotics. Food Sci Technol 44:158–63.

González-Molina E, Gironés-Vilaplana A, Mena P, Moreno DA, García-Viguera C. 2012. New beverages of lemon juice with elderberry and grape concentrates as a source of bioactive compounds. J Food Sci 77:C727–33.

Granato D, Branco GF, Nazzaro F, Cruz AG, Faria JAF. 2010. Functional foods and non-dairy probiotic food development: trends, concepts, and products. Compr Rev Food Sci Food Saf 9:292–302.

Grattan Jr. BJ. 2013. Plant sterols as anticancer nutrients: Evidence for their role in breast cancer. Nutrients 5:359–87

Gruenwald J. 2009. Fortification of beverages with products other than vitamins and minerals. In: Paquin P, editor. Functional and speciality beverage technology. Cambridge, UK: Woodhead Publishing Limited and CRC Press LLC. p. 92–106.

Gunathilake KDPP, Rupasinghe HPV, Pitts NL. 2013a. Formulation and characterization of a bioactive-enriched fruit beverage designed for cardio-protection. Food Res Int 52:535–41.

Gunathilake KDPP, Wang Y, Rupasinghe HPV. 2013b. Hypocholesterolemic and hypotensive effects of a fruit-based functional beverage in spontaneously hypertensive rats fed with cholesterol-rich diet. J Funct Foods 5:1392–401.

Gunja N, Brown JA. 2012. Energy drinks: health risks and toxicity. Res MJA 196:46–9.

Guo M. 2009. Prebiotics & probiotics. In: Guo M, editor. Functional foods: principles and technology. Boca Raton, Fla.: Woodhead Publishing Limited and CRC Press LLC. p. 113–60.

Gupta S, Cox S, Abu-Ghannam N. 2010. Process optimization for the development of a functional beverage based on lactic acid fermentation of oats. Biochem Eng J 52:199–204.

Gürakan GC, Cebeci A, Özer B. 2010. Probiotic dairy beverages: microbiology and technology. In: Yildiz F, editor. Development and manufacture of yogurt and other functional dairy products. Florence, S.C.: Taylor & Francis Group. p. 165–95.

Hasler CM. 2008. Health claims in the United States: an aid to the public or a source of confusion? J Nutr 138:1216S–20S.

Heckman MA, Sherry K, Gonzalez de Mejia E. 2010. Energy drinks: an assessment of their market size, consumer demographics, ingredient profile, functionality, and regulations in the United States. Compr Rev Food Sci Food Saf 9:303–17.

Higgins JP, Tuttle TD, Higgins CL. 2010. Energy beverages: content and safety. Mayo Clin Proc 85:1033–41.

Holzapfel WH. 2006. Introduction to prebiotics and probiotics. In: Goktepe I, Juneja VK, Ahmedna M, editors. Probiotics in food safety and human health. Florence, S.C.: Taylor & Francis Group. p. 1–33.

Jackson C-JC, Paliyath G. 2011. Functional foods and nutraceuticals. In: Paliyath G, Bakovic M, Shetty K, editors. Functional foods, nutraceuticals, and degenerative disease prevention. New York, N.Y.: John Wiley & Sons. p. 11–43.

Kausar H, Saeed S, Ahmad MM, Salam A. 2012. Studies on the development and storage stability of cucumber-melon functional drink. J Agric Res 50:239–48.

Kranz P, Braun N, Schulze N, Kunz B. 2010. Sensory quality of functional beverages: bitterness perception and bitter masking of olive leaf extract fortified fruit smoothies. J Food Sci 75:S308–11.

Larson N, DeWolfe J, Story M, Neumark-Sztainer D. 2014. Adolescent consumption of sports and energy drinks: linkages to higher physical activity, unhealthy beverage patterns, cigarette smoking, and screen media use. J Nutr Educ Behav 46: 181–7.

Lau T-C, Chan M-W, Tan H-P, Kwek C-L. 2013. Functional food: a growing trend among the health conscious. Asian Soc Sci 9:198–208.

Leong SY, Oey I. 2012. Effects of processing on anthocyanins, carotenoids and vitamin C in summer fruits and vegetables. Food Chem 133:1577–87.

Lima IFP, De Dea Lindner J, Soccol VT, Parada JL, Soccol CR. 2012. Development of an innovative nutraceutical fermented beverage from herbal mate (*Ilex paraguariensis* A.St.-Hil.) extract. Int J Mol Sci 13:788–800.

Lomer MCE, Parkes GC, Sanderson JD. 2008. Review article: lactose intolerance in clinical practice—myths and realities. Alimentary Pharm Therap 27:93–103.

Manning TS, Gibson GR. 2004. Prebiotics. Best Pract Res Cl Gastroenterol 18:287–98.

Marete EN, Jacquier J-C, O'Riordan D. 2011. Feverfew as a source of bioactives for functional foods: storage stability in model beverages. J Funct Foods 3:38–43.

Marsh AJ, Hill C, Ross RP, Cotter PD. 2014. Fermented beverages with health-promoting potential: past and future perspectives. Trends Food Sci Technol 38:113–24.

Martí N, Pérez-Vicente A, García-Viguera C. 2002. Influence of storage temperature and ascorbic acid addition on pomegranate juice. J Sci Food Agric 82:217–21.

Martinez-Saez N, Ullate M, Martin-Cabrejas MA, Martorell P, Genovés S, Ramon D, del Castillo MD. 2014. A novel antioxidant beverage for body weight control based on coffee silverskin. Food Chem 1:227–34.

Martins de Sá LZC, Castro PFS, Lino FMA, Bernardes MJC, Viegas JCJ, Dinis TCP, Santana MJ, Romao W, Vaz BG, Lião LM, Ghedini PC, Rocha ML, Gil ES. 2014. Antioxidant potential and vasodilatory activity of fermented beverages of jabuticaba berry (*Myrciaria jaboticaba*). J Funct Foods 8:169–79.

Maughan R.J. 2003. Functional ingredients in sports drinks. In: Watson DH, editor. Performance functional foods. Cambridge, UK: Woodhead Publishing Limited. p. 119–39.

Maughan RJ. 1991. Fluid and electrolyte loss and replacement in exercise. J Sports Sci 9:117–42.

Maughan RJ, Noakes TD. 1991. Fluid replacement and exercise stress—a brief review of studies on fluid replacement and some guidelines for the athlete. Sports Med 12:16–31.

McCarthy AL, O'Callaghan YC, Neugart S, Piggott CO, Connolly A, Jansen MA, Krumbein A, Schreiner M, Fitzgerald RJ, O'Brien NM. 2013. The hydroxycinnamic acid content of barley and brewers' spent grain (BSG) and the potential to incorporate phenolic extracts of BSG as antioxidants into fruit beverages. Food Chem 141:2567–74.

Meyer F, Timmons BW, Wilk B. 2013. Water, hydration and sports drink. In: Bagchi D, Nair S, Sen CK, editors. Nutrition and enhanced sports performance—muscle building, endurance, and strength. San Diego, Calif.: Academic Press. p. 377–84.

Mohagheghi M, Rezaei K, Labbafi M, Ebrahimzadeh SM. 2011. Pomegranate seed oil as a functional ingredient in beverages. Eur J Lipid Sci Technol 113:730–6.

Molina V, Médici M, de Valdez GF, Taranto MP. 2012. Soybean-based functional food with vitamin B_{12}-producing lactic acid bacteria. J Funct Foods 4:831–6.

Mollov P, Mihalev K, Shikov V, Yoncheva N, Karagyozov V. 2007. Colour stability improvement of strawberry beverage by fortification with polyphenolic copigments naturally occurring in rose petals. Innov Food Sci Emerg Technol 8:318–21.

Mozzi F, Ortiz ME, Bleckwedel J, De Vuyst L, Pescuma M. 2013. Metabolomics as a tool for the comprehensive understanding of fermented and functional foods with lactic acid bacteria. Food Res Int 54:1152–61.

Mukisa IM, Porcellato D, Byaruhanga YB, Muyanja CMBK, Langsrud T, Narvhus JA. 2012. The dominant microbial community associated with fermentation of Obushera (sorghum and millet beverages) determined by culture-dependent and culture-independent methods. Int J Food Microbiol 160:1–10.

Nagpal R, Kumar A, Kumar R, Behare PV, Jain S, Yadav H. 2012. Probiotics, their health benefits and applications for developing healthier foods: a review. FEMS Microbiol Lett 334:1–15.

Nazzaro F, Fratinni F, Coppola R, Sada A, Orlando P. 2009. Fermentative ability of alginate-prebiotic encapsulated *Lactobacillus acidophilus* and survival under simulated gastrointestinal conditions. J Funct Foods 1:319–23.

Nazzaro F, Fratinni F, Sada A, Orlando P. 2008. Synbiotic potential of carrot juice supplemented with *Lactobacillus* spp. and inulin or fructooligosaccharides. J Sci Food Agric 88:2271–6.

Nionelli L, Coda R, Curiel JA, Poutanen K, Gobbetti M, Rizzello CG. 2014. Manufacture and characterization of a yogurt-like beverage made with oat flakes fermented by selected lactic acid bacteria. Int J Food Microbiol 185:17–26.

Nocella G, Kennedy O. 2012. Food health claims—what consumers understand. Food Pol 37:571–80.

Nyanzi R, Jooste PJ. 2012. Cereal-based functional foods. In: Rigobelo EC, editor. Probiotics. Rijeka, Croatia: InTech. p. 161–96.

O'Connor EB, Barrett E, Fitzgerald G, Hill C, Stanton C, Ross RP. 2005. Production of vitamins, exopolysaccharides and bacteriocins by probiotic bacteria. In: Tamime A, editor. Probiotic dairy products. Oxford, UK: Blackwell Publishing Ltd. p. 167–94.

Ofori JA, Hsieh Y-HP. 2013. Novel technologies for the production of functional foods. In: Bagchi D, Bagchi M, Moriyama H, Shahidi F, editors. Bio-nanotechnology: a revolution in food, biomedical and health sciences. New York, N.Y.: John Wiley & Sons. p. 143–62.

Ordoudi SA, Mantzouridou F, Daftsiou E, Malo C, Hatzidimitriou E, Nenadis N, Tsimidou MZ. 2014. Pomegranate juice functional constituents after alcoholic and acetic acid fermentation. J Funct Foods 8:161–8.

Oro L. 2013. Role of yeast bioactive compounds in food and fermented beverages. PhD Thesis. Polytechnic Univ. of Marche, Faculty of Sciences, Ancona, Italy.

Otles S, Cagindi O. 2012. Safety considerations of nutraceuticals and functional foods. In: McElhatton A, Sobral PJA, editors. Novel technologies in food science. New York, N.Y.: Springer, p. 121–36.

Ottaway PB. 2009. Fortification of beverages with vitamins and minerals. In: Paquin P, editor. Functional and speciality beverage technology. Cambridge, UK: Woodhead Publishing Limited and CRC Press LLC. p. 72–91.

Ozen AE. 2012. Assessment of functional food and beverage consumption among the Balearic Islands population: gender, socio-demographic and lifestyle determinants. PhD Thesis. Univ. of Balearic Islands, Palma de Majorca, Spain.

Ozen AE, Pons A, Tur JA. 2012. Worldwide consumption of functional foods: a systematic review. Nutr Rev 70:472–81.

Özer B, Kirmaci HY. 2010. Functional milks and dairy beverages. Int J Dairy Technol 63:1–15.

Padilla-Zakou OI, Sullivan EK, Worobo RW. 2012. Juices and functional drinks. In: Zhao Y, editor. Specialty foods: processing technology, quality, and safety. Florence, S.C.: Taylor & Francis Group. p. 229–61.

Paquet E, Hussain R, Bazinet L, Makhlouf J, Lemieux S, Turgeon SL. 2014. Effect of processing treatments and storage conditions on stability of fruit juice based beverages enriched with dietary fibers alone and in mixture with xanthan gum. Food Sci Technol 55:131–8.

Patras A, Brunton NP, Da Pieve S, Butler F. 2009. Impact of high pressure processing on total antioxidant activity, phenolic, ascorbic acid, anthocyanin content and colour of strawberry and blackberry purees. Innov Food Sci Emerg Technol 10:308–13 .

Peres CM, Alves M, Hernandez-Mendoza A, Moreira L, Silva S, Bronze MR, Vilas-Boas L, Peres C, Malcata FX. 2014. Novel isolates of lactobacilli from fermented Portuguese olive as potential probiotics. Food Sci Technol 59:234–46.

Pescuma M, Hébert EM, Mozzi F, de Valdez GF. 2010. Functional fermented whey-based beverage using lactic acid bacteria. Int J Food Microbiol 141:73–81.

Prado FC, Parada JL, Pandey A, Soccol CR. 2008. Trends in non-dairy probiotic beverages. Food Res Int 41:111–23.

Pravst I. 2012. Functional foods in Europe: a focus on health claims. In: Valdez B, editor. Scientific, health and social aspects of the food industry. Rijeka, Croatia: InTech. p. 165–208.

Rathore S, Salmerón I, Pandiella SS. 2012. Production of potentially probiotic beverages using single and mixed cereal substrates fermented with lactic acid bacteria cultures. Food Microbiol 30:239–44.

Renuka B, Kulkarni SG, Vijayanand P, Prapulla SG. 2009. Fructooligosaccharide fortification of selected fruit juice beverages: effect on the quality characteristics. Food Sci Technol 42:1031–3.

Rodriguez EB, Flavier ME, Rodriguez-Amaya DB, Amaya-Farfán J. 2006. Phytochemicals and functional foods. Current situation and prospect for developing Countries. Segurança Alimentar e Nutricional 13:1–22.

Rodríguez-Roque MJ, Rojas-Graü MA, Elez-Martínez P, Martín-Belloso O. 2014. *In vitro* bioaccessibility of health-related compounds as affected by the formulation of fruit juice- and milk-based beverages. Food Res Int 62:771–8.

Rupasinghe HPV, Huber GM, Embree C, Forsline PL. 2010. Red-fleshed apple as a source for functional beverages. Can J Plant Sci 90:95–100.

Saarela M. 2009. Probiotics as ingredients in functional beverages. In: Paquin P, editor. Functional and speciality beverage technology. Cambridge, UK: Woodhead Publishing Limited and CRC Press LLC. p. 55–70.

Sanguansri L, Augustin MA. 2009. Microencapsulation in functional food product development. In: Smith J, Charter E, editors. Functional food product development. New York, N.Y.: John Wiley & Sons. p. 3–23.

Santos CC, Libeck BD, Schwan RF, 2014. Co-culture fermentation of peanut-soy milk for the development of a novel functional beverage. Int J Food Microbiol 186:32–41.

Serafini M, Stanzione A, Foddai S. 2012. Functional foods: traditional use and European legislation. Int J Food Sci Nutr 63:7–9.

Servili M, Rizzello CG, Taticchi A, Esposto S, Urbani S, Mazzacane F, Di Maio I, Selvaggini R, Gobbetti M, Di Cagno R. 2011. Functional milk beverage fortified with phenolic compounds extracted from olive vegetation water, and fermented with functional lactic acid bacteria. Int J Food Microbiol 147:45–52.

Shah NP, Ding WK, Fallourd MJ, Leyer G. 2010. Improving the stability of probiotic bacteria in model fruit juices using vitamins and antioxidants. J Food Sci 75:M278–82.

Shiby VK, Mishra HN. 2013. Fermented milks and milks products as functional foods-a review. Crit Rev Food Sci Nutr 53:482–96.

Simsek S, El SS, Kancabas Kilinc A, Karakaya S. 2014. Vegetable and fermented vegetable juices containing germinated seeds and sprouts of lentil and cowpea. Food Chem 156:289–95.

Sip A, Grajek W. 2009. Probiotics and prebiotics. In: Smith J, Charter E, editors. Functional food product development. New York, N.Y.: John Wiley & Sons. p. 147–77.

Sloan E. 2012. Beverage trends in 2012 and beyond. Agro Food Ind 23:8–12.

Soccol CR, De Dea Lindner J, Yamaguishi CT, Spier MR, Porto de Souza Vandenberghe L, Soccol VT. 2012. Probiotic nondairy beverages. In: Hui YH, editor. Handbook of plant-based fermented food and beverage technology. Florence, S.C.: Taylor & Francis Group. p. 707–28.

Song Y-R, Shin N-S, Baik S-H. 2014. Physicochemical and functional characteristics of a novel fermented pepper (*Capsicum annuum* L.) leaves-based beverage using lactic acid bacteria. Food Sci Biotechnol 23:187–94.

Sorenson D, Bogue J. 2009. Consumer-oriented development of functional beverages. In: Paquin P, editor. Functional and speciality beverage technology. Cambridge, UK: Woodhead Publishing Limited and CRC Press LLC. p. 421–50.

Sun-Waterhouse D. 2011. The development of fruit-based functional foods targeting the health and wellness market: a review. Int J Food Sci Technol 46:899–920.

Talwalkar A, Kailasapathy K. 2004. A review of oxygen toxicity in probiotic yogurts: influence on the survival of probiotic bacteria and protective techniques. Compr Rev Food Sci Food Saf 3:117–24.

Tangpricha V, Koutkia P, Rieke SM, Chen TC, Perez AA, Holick MF. 2003. Fortification of orange juice with vitamin D: a novel approach for enhancing vitamin D nutritional health. Am J Clin Nutr 77:1478–83.

Tarazona-Díaz MP, Alacid F, Carrasco M, Martínez I, Aguayo E. 2013. Watermelon juice: a potential functional drink for sore muscle relief in athletes. J Agric Food Chem 61:7522–8.

Tomar BS. 2014. Lactose intolerance and other disaccharidase deficiency. Indian J Pediatr 81:876–80.

Törrönen R, McDougall GJ, Dobson G, Stewart D, Hellström J, Mattila P, Pihlava J-M, Koskela A, Karjalainen R. 2012. Fortification of blackcurrant juice with crowberry: impact on polyphenol composition, urinary phenolic metabolites, and postprandial glycemic response in healthy subjects. J Funct Foods 4:746–56.

Valls J, Pasamontes N, Pantaleón A, Vinaixa S, Vaqué M, Soler A, Millán S, Gómez X. 2013. Prospects of functional foods/nutraceuticals and markets. In: Ramawat KG, Mérillon JM, editors. Natural products. Berlin: Springer-Verlag, p. 491–25.

Varela P, Tárrega A, Salvador A, Leal A, Flanagan J, Roller M, Feuiller N, Issaly N, Fiszman S. 2014. Diabetic and non-diabetic consumers' perception of an apple juice beverage supplemented with a *Fraxinus excelsior* L. seed extract having potential glucose homeostasis benefits. Food Sci Technol 57:648–55.

Walsh H, Cheng J, Guo M. 2014. Effects of carbonation on probiotic survivability, physicochemical, and sensory properties of milk-based symbiotic beverages. J Food Sci 79:M604–13.

Wang L, Bohn T. 2012. Health-promoting food ingredients and functional food processing. In: Bouayed J, Bohn T, editors. Nutrition, well-being and health. Rijeka, Croatia: InTech. p. 201–24.

Waters DM, Mauch A, Coffey A, Arendt EK, Zannini E. 2013. Lactic acid bacteria as a cell factory for the delivery of functional biomolecules and ingredients in cereal-based beverages: a review. Crit Rev Food Sci Nutr, in press.

Wootton-Beard PC, Ryan L. 2011. Improving public health? The role of antioxidant-rich fruit and vegetable beverages. Food Res Int 44:3135–48.

Woyengo TA, Ramprasath VR, Jones PJ. 2009. Anticancer effects of phytosterols. Eur J Clin Nutr. 63:813–20.

Yang Y. 2008. Scientific substantiation of functional food health claims in China. J Nutr 138:1199S–205S.

Yeo S-K, Ewe J-A, Tham CS-C, Liong M-T. 2011. Carriers of probiotic microorganisms. In: Liong M-T, editor. Probiotics, biology, genetics and health aspects. Berlin: Springer-Verlag. p. 191–220.

Yuan T, Li L, Zhang Y, Seeram NP. 2013. Pasteurized and sterilized maple sap as functional beverages: chemical composition and antioxidant activities. J Funct Foods 5:1582–90.

Zannini E, Mauch A, Galle S, Gänzle M, Coffey A, Arendt EK, Taylor JP, Waters DM. 2013. Barley malt wort fermentation by exopolysaccharide-forming *Weissella cibaria* MG1 for the production of a novel beverage. J Appl Microbiol 115:1379–87.

Zeidán-Chuliá F, Gelain DP, Kolling EA, Rybarczyk-Filho JL, Ambrosi P, Terra SR, Pires AS, da Rocha JBT, Behr GA, Moreira JCF. 2013. Major components of energy drinks (caffeine, taurine, and guarana) exert cytotoxic effects on human neuronal SH-SY5Y cells by decreasing reactive oxygen species production. Oxid Med Cell Longev 2013:791–795.

Zhang X, Wang W, Xiao K. 2010. Novel omics technologies in nutraceutical and functional food research. In: Bagchi D, Lau F, Bagchi M, editors. Genomics, proteomics, and metabolomics in nutraceuticals and functional foods. New York, N.Y.: Wiley-Blackwell. p. 11–22.

Zhao D, Shah NP. 2014. Antiradical and tea polyphenol-stabilizing ability of functional fermented soymilk—tea beverage. Food Chem 158:262–9.

