Chapter 13
Novel Fermented Fruit and Vegetable-Based Products

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13.1 Plant-Based Functional Products

Functional foods development represents one of the most innovative trends in food industry. Between 2005 and 2009, the global launches of functional products have been reported more than doubled, from 904 to 1859 (Valls et al., 2013). Fermented dairy products are the most common vehicles for functional components, though the research is driven toward plant-based functional foods, as the consequence of the ongoing trend of vegetarianism, the level of cholesterol of dairy products, and the increasing prevalence of the lactose intolerance. Fermentation represents a valuable biotechnology to improve nutritional and functional features of plant material. In this overview, several strategies have been implemented in order to develop novel fermented plant-based functional foods. Microorganism functionality may be exploited to increase bioactive compounds during fermentation. Innovation also involves the testing of novel formulation with natural ingredients or by-products food industries as functional ingredients. Moreover, foods may be fortified with probiotics and prebiotics.

13.1.1 Microorganism as Cell Factories for Functional Food Development

Bioprocessing of plant materials using bacteria (e.g., lactic acid bacteria, bifidobacteria, *Bacillus* spp., and *Gluconobacter* spp.), yeasts (e.g., *Saccharomyces cerevisiae*), and fungi (e.g., *Aspergillus* spp., *Rhizopus* spp., and *Monascus* spp.) provides

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strategies to produce bioactive compounds and enhance food nutraceutical properties. Microorganisms may improve bioavailability of vitamins, minerals, amino acids (e.g., γ-aminobutyric acid), and phytochemicals (e.g., phenolics and sterols) as well as lead to a marked increase of microbial metabolites (e.g., organic acids, exopolysaccharides, and conjugated linoleic acids) (Frédéric & De Vuyst, 2014).

A common application of fermentation is the manufacture of foods enriched with antioxidant compounds. Several phenolic derivatives showed higher antioxidant property than their precursors after microbial bioconversion. Besides, bioconversion of phenolic compounds, fermentation may also promote other alterations in the food properties, with effect on human health. Fermented cherry and pomegranate juices, broccoli puree, cowpeas, and onions have been enriched in phenolic derivatives with high bioavailability, due to bioconversion using selected *Lactobacillus* spp. (Di Cagno, Surico, et al., 2011; Filannino et al., 2013; Filannino, Bai, Di Cagno, Gobbetti, & Gänzle, 2015). In fact, it was found that phenolic aglycones have higher antioxidant activity and human bioavailability than their glycosides. Nevertheless, human tissues and biological fluids do not possess esterases, capable of hydrolyzing phenolic glycosides, and only the colonic microbiota would be capable of carrying out this hydrolysis (Manach, Scalbert, Morand, Rémés, & Jiménez, 2004). Phenolic esterases are widespread in *Lactobacillus* spp., and allow to metabolize phenolic glycosides that are abundant in plant matrices, improving the inherent functional value of fermented fruits and vegetables. Also the fermentation of mung beans by *Rhizopus oligosporus* was shown as being able to mobilize the conjugate forms of phenolics and improves their health-linked functionality (Randhir & Shetty, 2007).

A further approach includes the release of bioactive peptides exploiting the proteolytic system of microorganisms. Plant proteins have been less studied than animal proteins, though they may represent an excellent source of bioactive peptides with antihypertensive, antioxidative, anti-obesity, immunomodulatory, antidiabetic, hypocholesterolemic, or anticancer properties. Plant peptides include hypogin (peanut), angularin (adzuki bean), lunasin (soybean and barley), Bowman–Birk inhibitors (soybean and lentil), and trypsin inhibitors (mustard) (Kadam, Tiwari, Álvarez, & O'Donnell, 2015).

Fermentation also represents an effective biotechnological approach for production/extraction of microbial metabolites useful for pharmaceutical purpose or as food additives. A promising strategy is the use of by-products as a source of active ingredients to produce functional foods. By-products generated during agricultural production or industrial food processing (e.g., pomace, seeds, peels, straw, sugarcane bagasse, corn stover, cobs, and husks) contain soluble sugars, fiber, proteins, and polyphenols that may be metabolized by a range of microorganisms into valuable bioactive compounds. Protein-rich by-products may represent a valuable substrate for peptide-based functional food development. The bioconversion of lignocellulosic materials for the production and extraction of bioactive phenolic compounds can also be considered. Recently, pomegranate husks, green coconut husk, and cranberry pomace were successfully used as fruitful sources for ellagic and ferulic acids and other phenolic compounds through bioprocessing with *Aspergillus niger*, *Lentinus edodes*, and *Phanerochaete chrysosporium*. Enzymes such as α-amylase, laccase, β-glucosidase, tannin acyl hydrolase, and ellagitannin acyl hydrolase, among others, play a key role in bioprocessing of lignocellulosic substrates. Though the enzymes involved are mainly released by fungi, the enzymology of bacterial lignin breakdown is currently underway. *Bacillus* sp. strains were positively evaluated for their alkali lignin-degrading ability. *Lactobacillus pentosus*, *Pediococcus pentosaceus,* and *Pediococcus acidilactici* strains were also proposed for efficient bioconversions of lignocellulosic feedstock. The advantage of harnessing the biosynthetic ability of bacteria rather than fungi is that bacteria are better suited to implementation of genetic engineering strategies (Boguta, Bringel, Martinussen, & Jensen, 2014; Chang, Choi, Takamizawa, & Kikuchi, 2014; Martins et al., 2011).

Recently, wastes and by-products occurring in the food supply chain have received attention to produce single-cell protein (SCP) as protein supplement for both human food and animal feeds. New sources of protein can alleviate the world's protein deficit occurring from conventional protein sources. Lignocellulosic biomass is rich in fiber and fermentable sugars, but low in protein content. Microorganisms, such as filamentous fungi, yeast, and bacteria, may be involved in bioconversion of by-products (e.g., pomace, peels, straw, corn stover, cobs, and husks) to produce biomass rich in proteins and amino acids. As plant proteins are generally low in lysine, a major advantage of SCP is its high lysine content. Microorganisms selected for this purpose have to show a high specific growth rate and biomass yield, and a high affinity for the substrate with a low requirement for growth factor supplementation. Yeast such as *Kluyveromyces* spp., *Candida* spp., and *S. cerevisiae* were successfully used in SCP production. Filamentous fungi have received great attention due to their ability to use a large number of complex growth substances such as cellulose and lignin. Cellulose is the most abundant organic compound on earth. Bacteria and fungi may synthesize cellulases under aerobic or anaerobic conditions.

Compared to monocultures, mixed cultures may lead to better substrate utilization and increased productivity due to the synergistic interactions between compatible microorganisms (Gutierrez-Correa, Portal, Moreno, & Tengerdy, 1999). For instance, coculture of cellulolytic moulds (e.g., *Aspergillus niger*) and yeasts (e.g., *Candida tropicalis*) has shown an increase in protein content of apple pomace probably because fermentable sugars obtained from cellulolytic mould and the yeast would have used sugars released (Bhalla & Joshi, 1994).

Fermentation may improve the nutritional properties of foods by removing antinutrients (e.g., oxalate, protease and α-amylase inhibitors, lectins, condensed tannins, and phytic acid) and harmful components (e.g., mycotoxins, biogenic amines, and cyanogenic glycosides). In order to reduce mycotoxins levels in foods and feeds, degradation by microorganisms (e.g., *Saccharomyces* spp., *Acinetobacter calcoaceticus*, lactic acid bacteria, bifidobacteria, or *Aspergillus* spp.) was reported in literature as an effective strategy (Bejaoui, Mathieu, Taillandier, & Lebrihi, 2004). Further examples include the removal of raffinose, stachyose, and verbascose in soy, to prevent flatulence and intestinal cramps, and the decrease in levels of proteinase inhibitors in legumes, to improve the protein digestibility.

13.1.2 Novel Formulations with Natural Ingredients

New product development is a constant challenge for functional foods sector. Beneficial synergies among food ingredients, food formulation, and processing methods can be an effective strategy for food innovation. Recently, a novel protocol for pilot scale production of fermented cherry puree was proposed by addition of stem infusion (10 %, v/v) to improve the phenolic profile (Di Cagno, Surico, et al., 2011). The selection of the best formulation is a crucial step for the design and development of novel foods in order to obtain suitable physicochemical, functional, and sensorial attributes with extended shelf-life, chemical stability, and reasonable price. A critical factor to be considered is the knowledge of the interactions that might occur when several ingredients are mixed together. These ingredients may undergo to various chemical and/or physical changes (e.g., precipitation, oxidation, insolubility, and degradation) and may affect the survival of microorganisms. The selection of the growth substrate should be based on the nutritional requirements of microorganisms, and in some cases supplementation of substrate may be required. Fermentation of mixed substrates may have advantages such as the possibility to develop a complete fermentation process without need for extra nutrients. A recent study aimed at investigating the capacity of selected lactic acid bacteria to enhance functional features of *Echinacea purpurea* with the prospect of its application as functional food (Rizzello et al., 2013). Since *Echinacea* powder suspension in distilled water allowed a very poor growth of *L. plantarum* starters. Yeast extract or grape must were added to optimize bacterial growth conditions. Grape must was also used as a substrate to synthesize γ-aminobutyric acid (GABA) by *L. plantarum* for the manufacture of a functional beverage (Di Cagno, Mazzacane, et al., 2010).

13.1.3 Fortification of Fermented Fruits and Vegetables with Probiotics

There is a strong interest toward the development of fermented plant-based functional products fortified with probiotics. Most probiotics conveyed through fermented foods and food complements belong to *Bifidobacterium* and low GC (guanine and cytosine) percentage lactic acid bacteria. The use of yeast as a probiotic food supplement is still restricted and is not completely elucidated, although they represent a significant part of the characteristic microbiota of several traditional fermented products associated to health benefits. To date, *Saccharomyces boulardii* is the main recognized probiotic yeast. More than other food matrices, raw fruits and vegetables may represent the ideal vehicle for functional health ingredients, since they are inherently rich in beneficial nutrients and have a microstructure comprised of sites (e.g., intercellular spaces, stomas, lenticels, capillaries, irregularities naturally occurring, and tissue lesions), which favors the microbial internalization and protection. Moreover, indigestible molecules (e.g., fiber, inulin, and fructo-oligosaccharides) protect probiotic microorganisms from the acidic environment of the stomach and are a source of nutrients, which positively influences bacterial survival. However, the lack of certain vitamins and essential amino acids in some plant species may limit the growth of probiotics. Microbial viability and functionality is strongly dependent on the strain and on the nature of plant substrate. Sheehan, Ross, and Fitzgerald (2007) reported significant differences with respect to the acid resistance property of *Lactobacillus* spp. and *Bifidobacterium* spp. in orange, pineapple, and cranberry juices. All of the strains screened survived for longer in orange and pineapple juice than in cranberry juice, and few *Lactobacillus casei*, *Lactobacillus rhamnosus*, and *Lactobacillus paracasei* strains showed the greatest robustness. Although probiotic bacterial strains are currently isolated and characterized mainly from the human gastrointestinal tract, raw fruits and vegetables may represent an alternative source of novel probiotic candidates able to survive to gastric and intestinal fluids, capable of adhering to the gut epithelium and exerting a beneficial effect on the health of the host (Vitali et al., 2012). Inherent chemical and physical features of raw fruits and vegetables mimic those of the human gastrointestinal tract (e.g., extremely acid environment, high osmotic pressure, poor nutrient profile, and presence of indigestible nutrients and antibacterial compounds). Thus, adaptation to the harsh environmental conditions of plant matrices makes plant-derived bacteria capable of reaching the intestine in the living state. Several works showed that the resistance ratio of plant-derived lactic acid bacteria to gastric juices and bile may be comparable or even higher than animal-derived lactic acid bacteria.

13.2 Microbial Starter Selection for Novel Fermented Plant-Based Foods

Today, lactic acid bacteria play a prominent role in the world food supply, performing the main bioconversions in fermented products. For the manufacturing of commercial novel fermented plant-based foods, spontaneous fermentation with unsterilized raw vegetables and fruits leads to the growth of various lactic acid bacteria, which makes it difficult to control the fermentation process. In some cases, the alcoholic fermentation takes place concomitantly. Overall, the spontaneous fermentation of vegetables and fruits includes the succession of hetero- and homofermentative lactic acid bacteria, together with or without yeasts (Plengvidhya, Breidt, & Fleming, 2004). Notwithstanding the reliable value of the spontaneous fermentation to stabilize and preserve raw vegetables and fruits (e.g., cucumbers, onions, eggplants, red-beets, capers, lychee, cocoa beans, and persimmon), a number of factors are in favor of the use of selected starters. Some of these factors include the risk of fermentation failure, the inadequate inhibition of spoilage and pathogen microorganisms, and the undesirable and unpredictable variations in the sensory, nutritional, and rheology properties (Di Cagno, Coda, De Angelis, & Gobbetti, 2013). The use of starter cultures was considered as an alternative to address these outstanding drawbacks. Recent trends suggest that the demand for starter cultures is on the rise. Overall, two main options may be pursued for the controlled lactic acid fermentation of fruits and vegetables include the use of autochthonous or allochthonous starters (Di Cagno et al., 2013). Autochthonous starter means isolated from and reused on the same raw matrix, apart from the geographical origin. Allochthonous starter means isolated from certain raw matrices but used to ferment various products. Obviously, commercial starters, which are used to ferment a variety of vegetables and fruits, mostly coincide with the above definition of allochthonous strains. Authorized lists of microorganisms with certified use in food fermentations, which cover a wide range of food matrices, including vegetables and fruits, were recently published (Bourdichon et al., 2012). These lists may represent a de facto reference of food cultures, which should be consulted to select starter for fermentation of raw vegetables and fruits. Usually, commercial starters are not previously selected to ferment a specific vegetable or fruit matrix and in some cases, may present several limitations (1) the selection did not consider other features than rapid acidification; (2) the adaptation to the main sensory and functional properties of the matrix is poor; (3) the metabolic flexibility is low; and (4) the diversity did not reflect the ecosystem where they have to be used. Consequently, highly performing commercial/allochthonous starter cultures are very rare. Selection of starter cultures within the autochthonous microbiota of fruits and vegetables should be recommended since autochthonous cultures may ensure prolonged shelf-life and targeted nutritional, rheology, and sensory properties. Indeed, autochthonous strains always had better performances than commercial/allochthonous strains. Not all the strains that compose the lactic acid bacteria microbiota of vegetables and fruits may guarantee the same performance during processing. Therefore, their selection is indispensable. The main criteria for selecting starters to be used for vegetable fermentation are the (1) rate of growth; (2) rate and total production of acids which, in turn, affects the changes of pH; and (3) environmental adaptation/tolerance. Studies on starters to be used for plant-based foods have mainly focused on the production of products with extension of the optimal ripening period, improved sensory features, functionality, and enhanced safety by using predominant lactic acid bacteria, acid-resistant strains inhibiting overacidifying microorganisms, and bacteriocin-producing strains. Three main criteria for selecting lactic acid bacteria as starters for novel fermented plant-based foods are shown in Fig. 13.1. Predominance of growth by a species of lactic acid bacteria is influenced by the chemical and physical environment in which it has to compete. *L. plantarum*, which predominates the later stage of vegetable fermentation due to its high acid tolerance and metabolic versatility, seems a likely choice when homolactic fermentation is desired. Moreover, robustness of autochthonous starters throughout fermentation and storage processes are able to achieve high cell numbers (ca. 8.0–9.0 log cfu g^{-1}) is an indispensable prerequisite to ensure both safety and potential probiotic properties of the product. The synthesis of exopolysaccharides is another metabolic trait to be considered for the selection, especially for lacto-juices and -puree. In addition, the capacity of lactic acid bacteria to synthesize protopectinases, which may enhance the viscosity of fruit matrices, may be an important characteristic for starters. Growth and viability

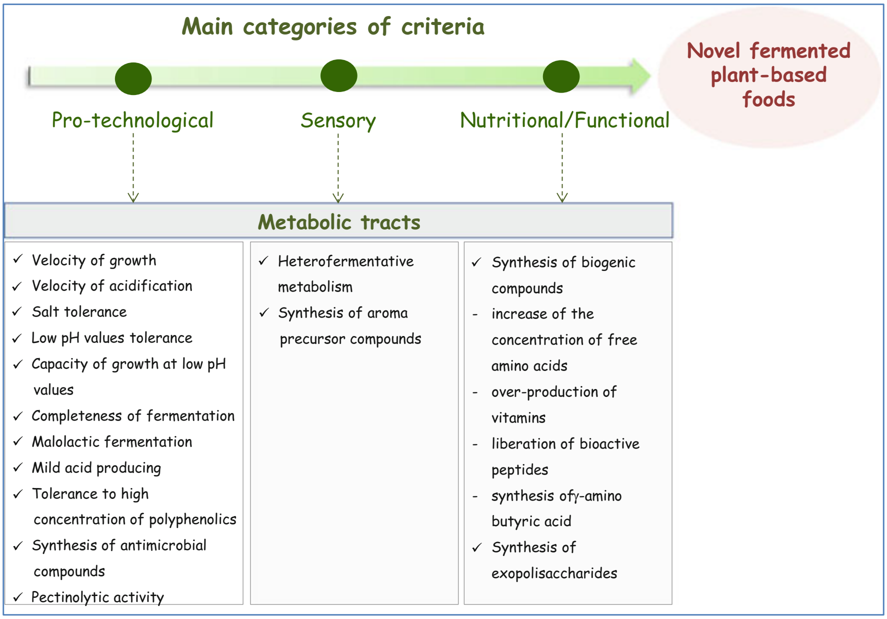

Fig. 13.1 Main criteria for selecting lactic acid bacteria as starters for novel fermented plant-based foods

of lactic acid bacteria, in particular *L. plantarum* and pediococci, are frequently shown on plant materials where polyphenolic compounds are abundant. *L. plantarum* has shown the metabolic capacity to degrade some phenolic compounds and/or other related chemical compounds. Exploitation of bacteriocinogenic lactic acid bacteria on common spoilage and pathogenic microorganisms of raw vegetables and fruits have been extensively investigated. Although nisin is the only purified bacteriocin used thus far in industrially processed foods, many bacteriocins produced by various lactic acid bacteria may have potential applications in biopreservation from common spoilage (yeasts and molds) and pathogenic (e.g., *Listeria innocua*, *Listeria monocytogenes,* and *Escherichia coli*) microorganisms.

13.3 Novel Plant-Based Fermented Products

Rapidly evolving technological capabilities has led to several innovations in plant-based products. These consumer-oriented innovations are mainly related to the ingredient exploration and development. The focus of food product development process is to improve convenience, nutritional, functional, and hedonistic features of fruits and vegetables. Particular attention is addressed toward plant-based functional beverages and fresh-cut minimally processed products.

13.3.1 Plant-Based Beverages

Nowadays, there is a strong tendency toward consumption of fresh-like, highly nutritional value, health-promoting, and rich flavor beverages, for example, fermented juices, smoothies, and yogurt-like product. Nondairy beverages market is supposed to have an annual growth rate of 15 % during the next few years (Marsh, Hill, Ross, & Cotter, 2014). One of the most attractive opportunities is the development of lactic acid-fermented fruit and vegetable juices, also named "lactojuices," which have been shown to have considerable market value and consumer acceptance, as they are perceived as healthy and refreshing beverage. The technological options for the manufacture of fermented vegetable juices mainly include the following three (1) spontaneous fermentation by autochthonous microbiota, (2) fermentation by selected starter cultures added into raw vegetables, and (3) fermentation of mild heat-treated vegetables by starter cultures. Plethora of literature regarding fermented lactojuices is available. Various fruits and vegetables including watermelon, sapodilla, carrot, potato, beetroot, pepper, parsley, lettuce, lemon, cabbage, spinach, tomato, pomegranate, blackcurrant, orange, grapes, sweet potatoes, apple, pear, and cashew apple have been employed for the production of lactojuices. Pomegranate has gained great popularity during the last decade due to the growing scientific evidence for its high nutritional and functional value, thus different fermentation technologies were recently applied to develop novel functional juices (Filannino et al., 2013; Mousavi, Mousavi, Razavi, Emam-Djomeh, & Kiani, 2011). Despite health benefits has been poorly demonstrated with clinical trials or even animal models, in most of cases in vitro studies stated the positive effects of fermentation on the health-promoting properties of juices (e.g., antioxidant, immunomodulation, antihyperglycemia, antihypertensive, ACE inhibitor, antitumor, bile acid-binding, and hemagglutinating activities). Lactic acid fermentation has been successfully used to preserve or improve sensory properties (texture, flavor, and color) of fruit and vegetable juices (Di Cagno et al., 2013). Fermentation by *L. fermentum* has been successfully applied in deacidification of *Prunus mume* fruits, since the fresh fruits are unsuitable for direct consumption due to the high inherent acidity and amygdalin (bitter taste), with a good prospect in the development of probiotic beverage (Yu et al., 2015).

The use of selected starter cultures may also improve juice yield thank to the activity of pectinolytic enzymes. The fermentation by selected lactic acid bacteria has been largely used to enhance the antimicrobial, antioxidant, and immunomodulatory features of several medicinal plants. For instance, an innovative functional and probiotic fermented beverage has been developed using herbal mate fermented by . A major advantage of this product is the compliance to organic claims, while providing caffeine and other phytostimulants without the addition of synthetic components in the formulation (Lima, De Dea Lindner, Soccol, Parada, & Soccol, 2012).

The probiotication of several fruit and vegetable juices with lactic acid bacteria and bifidobacteria was also successfully reported. Several options are currently pursued for improving bacterial viability in plant juices. The addition of yeast autolysate (e.g., spent brewer's yeast) into the juices increases the number of lactic acid bacteria during the fermentation and reduces the time of fermentation. The prebiotic effect of the cashew apple juice fermented by selected *Leuconostoc mesenteroides* was increased due to the addition of prebiotic oligosaccharides (Vergara, Honorato, Maia, & Rodrigues, 2010). The exposure of bacteria to a sublethal stress might induce a kind of resistance and an adaptive stress response. Cultivation in an acidified laboratory medium (acid stress) or containing vanillic acid (phenol stress) or in a substrate added with variable amounts of fruit juice was proposed as a successful protocol to increase *Lactobacillus reuteri* survival in fruit juices (Perricone, Bevilacqua, Altieri, Sinigaglia, & Corbo, 2015). Furthermore, *L. casei* strains gained higher resistance to simulated gastric digestion after the exposure to the acidic conditions of fruit juices during refrigeration (Céspedes, Cárdenas, Staffolani, Ciappini, & Vinderola, 2013). Stability and sensory acceptance must be considered during the development of probiotic fermented juices (Granato, Branco, Nazzaro, Cruz, & Faria, 2010). Though several novel probiotic juices were found to have good aroma and flavor compared to nonprobiotic juices, however, in some cases unsuitable aromas and flavors may occur. A proper selection of the fruit matrices, probiotic strains, and eventually the addition of other ingredients may contribute to develop a palatable beverage. Nevertheless, it was showed that consumers, even though preferring the sensory properties of conventional juices to their functional counterparts, are inclined to prefer probiotic juices over the conventional one if the health benefits information is provided (Luckow & Delahunty, 2004).

Smoothies are one of the best examples of innovative vegetable-based fermented beverage. The manufacture of smoothies is based on the use of mixture of fruits and vegetables, often after removing seeds and peel, which are mainly processed to pulp or puree (Qian, 2006). In most of the cases, mixtures of fruits and vegetables are selected based on color, flavor, drinkable texture and, especially, to guarantee high concentration of nutrients with low energy content. Recently, a novel protocol for the manufacture of fermented red and green smoothies was established (Di Cagno, Minervini, Rizzello, De Angelis, & Gobbetti, 2011). White grape juice and *Aloe vera* extract were mixed with red (cherries, blackberries prunes, and tomatoes) or green (fennels, spinach, papaya, and kiwi) fruits and vegetables and were fermented by mixed autochthonous starters. A potential probiotic banana puree was obtained through fermentation by using k-carrageenan immobilized *L. acidophilus.* Cell immobilization may provide protective effects resulting in higher cell density, thus improving the fermentation efficiency (Tsen, Lin, & King, 2004, 2009).

The so-called vegetable milks might be also used as raw materials to develop yogurt-like products. Vegetable milks are mainly obtained from soy, cereals, and nuts, moreover others minor raw materials including hemp, sunflower, legumes (e.g., lupin and peanut seeds), and tubers (e.g., tiger nuts) are also used (Bernat, Cháfer, Chiralt, & González-Martínez, 2014a, 2014b; Bernat, Cháfer, Chiralt, Laparra, & González-Martínez, 2015; Beuchat & Nail, 1978; Wakil, Ayenuro, & Oyinlola, 2014). Yogurt-like products making process involves the following main steps (1) milk conditioning to the optimal growth temperature of the starters; (2) inoculation and incubation procedures; and(3) cooling at 4 °C (Bernat et al., 2014a). Proteins coagulation, and serum separation during storage, may cause problems associated with physical stability. The addition of hydrocolloids, such as xanthan gum, modified starches, pectin, and cellulose derivatives, can be used to enhance physical stability. In situ production of oligosaccharides and exopolysaccharides by lactic acid bacteria positively affect the texture, since these compounds act as emulsifiers or stabilizers and increase viscosity and mouth feel (Coda, Lanera, Trani, Gobbetti, & Di Cagno, 2012). Probiotication was successfully reported for several vegetable milks. Prebiotic compounds (e.g., starch and fibers) may be added both to improve textural features and to support the probiotics survival (Bernat et al., 2014b, 2015; Mustafa et al., 2009; Santos, Libeck, & Schwan, 2014).

13.3.2 Fresh-Cut (Minimally Processed) Fruits and Vegetables

Fresh-cut (minimally processed) fruits and vegetables are obtained by trimming and/or peeling and/or cutting and packaging and are characterized by convenience and ability to maintain their freshness. Fermented pineapple slices by autochthonous lactic acid bacteria, also without any heat treatment, is an example of shelf-stable minimally processed fruit combining agreeable nutritional and sensory properties, and probiotic potential (Di Cagno, Cardinali, et al., 2010). Fermentation by autochthonous and selected lactic acid bacteria strains was demonstrated to guarantee an extended shelf-life for red and yellow peppers, which also maintained agreeable texture and sensory properties (Di Cagno et al., 2009). Fresh-cut apple wedges was developed by applying probiotic bacteria (*L. rhamnosus* GG) and prebiotics (oligofructose and inulin). The alginate coating, which was used as a carrier for prebiotic supplements, beneficially affected the stability of inherent polyphenols and it was able to retain apple volatiles slightly better than uncoated apple wedges (Rößle, Brunton, Gormley, Ross, & Butler, 2010). The alginate- and gellan-based edible coatings were successfully applied to support *Bifidobacterium lactis* viability on fresh-cut apple and papaya (Tapia et al., 2007). A protective effect against relevant foodborne pathogens was also reported. *L. rhamnosus* GG in fresh-cut apple wedges reduced the growth of *Listeria monocytogenes* (Alegre, Viñas, Usall, Anguera, & Abadias, 2011). *L. plantarum* B2 and *L. fermentum* PBCC11.5 showed a good ability to reduce the level of *Lis. monocytogenes* on artificially contaminated melons. Based on human trials, *L. paracasei* IMPC2.1 was recovered from fecal samples of the volunteers fed with artichoke heads carrying the strain, indicating that artichokes are suitable carriers for transporting bacterial cells into the gastrointestinal tract (Valerio et al., 2006).

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