Lactic Acid Bacteria

Subjects: Microbiology

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The antibacterial effect of lactic acid bacteria is attributed to its ability to produce antimicrobial compounds, including bacteriocins, with strong competitive action against many microorganisms. The use of bacteriocins, both separately and in combination with edible coatings, is considered a very promising approach for microbiological quality, and safety for postharvest storage of raw and minimally processed fruits and vegetables.

Keywords: postharvest management ; lactic acid bacteria ; fresh fruits and vegetables ; food safety ; foodborne bacterial pathogens ; natural antimicrobials ; edible coatings ; bacteriocin ; biopreservatives ; antimicrobial efficacy

1. Abstract

Lactic acid bacteria (LAB) are generally accepted as safe microorganisms playing important roles in food fermentation and preservation, either by the presence of natural microbiota or through the addition of starter cultures under controlled conditions. The preservation effect exerted by LAB is mainly due to the production of lactic and acetic acids but also due to several other antimicrobial compounds with important anti-bacterial effect. Fruit and vegetables are an important part of human diets and provide multiple health benefits. However, due to the short shelf-life of fresh and minimally-processed fruit and vegetables, significant losses occur throughout the food distribution chain. Shelf-life extension requires preserving both the quality and safety of food products. Increasing the shelf-life of fresh and fresh-cut fruit and vegetables is challenging, but can be achieved by physical, chemical or biological methods. Foodborne diseases are a growing public health problem worldwide, particularly for infants, children and the elderly. Consumption of fresh fruits and vegetables is associated with a growing number of foodborne outbreaks due to bacterial contamination of these products. Postharvest management of fresh fruits and vegetables storage can be achieved through the use of lactic acid bacteria.

2. Introduction

A healthy diet includes eating fruits and vegetables; their consumption is recommended by several government agencies because of their nutritional and medicinal properties [1] and low energy content [2]. Heart disease, colon cancer, obesity, and diabetes are some of the diseases that can be reduced with a high intake of fruits and vegetables [3]. Their consumption has increased in recent years, making them essential on a daily basis due to their abundance of nutrients [4]. In particular, in the last decade, the increased demand for fresh fruits and vegetables (whole and cut) in many industrialized nations has been covered partly from the production of minimally processed fruits and vegetables, as they are healthy and convenient foods. Traditional methods tend to be replaced by minimal processing methods, by providing fruits and vegetables that retain their quality for more than the usual time [5][6]. Two groups of molecules in the chemical composition of fruits and vegetables exist: nutritive molecules and non-nutritive phytochemicals [7]. Among nutritive molecules, vitamins, minerals, fibers, and micro and macronutrients are the most important, while phenolic compounds, flavonoids, and bioactive peptides belong to non-nutritive phytochemicals and have beneficial properties for human health [7]. The beneficial effect of all these molecules is proved in their action as receptors against free radicals [8]. According to the recent edition of Dietary Guidelines for Americans, published in 2016, from the U.S. Department of Health and Human Services (HHS) and U.S. Department of Agriculture (USDA), fruits and vegetables, should hold half the daily energy intake [9]. Moreover, vegetables with different colors (red, green, orange) from all categories, and whole fruits, are key recommendations in a healthy eating pattern. According to the International Fresh-Cut Produce Association (IFPA), fresh-cut produce is defined as “any fruit or vegetable or combination thereof that has been physically altered from its original form, but remains in a fresh state” [10]. Fresh-cut fruits and vegetables can be washed, trimmed, peeled, and chopped, creating 100% easy-to-use products that are still fresh, maintaining all of the characteristics during packaging (without further processing) and under refrigeration [11]. ‘Ready-to-eat’, ‘fresh-cut’, ‘easy- to-use’, or ‘pre-cut produce’ are some others designations used for minimally processed fruits and vegetables [12].

Fresh-cut fruits and vegetables are extremely perishable products that have a very short shelf life and physiological deterioration; biochemical changes and microbial degradation can occur during their marketing. All of these changes can cause significant degradation in quality of characteristics, such as color, aroma, and taste, and lead to the growth of undesired and harmful pathogens, limiting shelf life [5]. In addition, even minimal processing of fresh fruits and vegetables, such as cutting and peeling, leads to the leakage of cellular content around the injuring points, increasing the risk of a microbial infection, as these points are full of minerals, sugars, vitamins, and other nutrients [13][14]. Moreover, upcoming rapid tissue aging can significantly reduce the life of fresh-cut fruits and vegetables [15]. Browning, softening, and off-flavor development are some of the signs that may appear in fresh fresh-cut fruits and vegetables [16]. Mechanical wounding of fresh fresh-cut fruits and vegetables also increases the rate of respiration, which is directly connected with short postharvest life [17]. These products are ready for consumption without any further possible microbiological treatment, so quality and safety issues are very urgent for consumer health [6]. Damage to the outer surface of cut fruits and vegetables favors the survival and proliferation of foodborne pathogens, especially at temperatures above 4 °C. Lower temperatures can ensure a reduction in dynamic multiplication, but do not completely stop the survival of some microorganisms [18]. Microbial growth, in the case of fresh-cut fruits and vegetables, is significantly favored by the high water content of a large number of chopped tissues, as well as by the low or neutral pH that has the most vegetables and fruits, respectively [19].

In order to prolong storage life of fresh and minimally processed fruits and vegetables, many physical, chemical, and biological means and treatments have been proposed. Disinfection and washing are the main procedures used to reduce the population of pathogenic microorganisms (including their effect on the safety and quality of fresh and minimally processed fruits and vegetables). Among them, chlorine is a predominant treatment, which is added to water used to wash fresh-cut fruits and vegetables, although it has limited antimicrobial efficacy as it can only achieve 1–2 logarithmic reductions in pathogenic microorganisms [20]. The use of chlorine as a sanitizing agent poses serious risks to human health due to production of carcinogenic halogenated compounds [15]. European countries, such as Germany, Switzerland, the Netherlands, Denmark, and Belgium have taken into account all of the health issues that have arisen, and have banned the use of chlorine in disinfection of fresh and minimally processed fruits and vegetables. Another widely used disinfection practice is the use of NaClO with 50–150 mg L^{-1}, which also has potential risks [21]. Different chemical alternatives to chlorine have been used, such as chlorine dioxide, and acidified sodium chlorite. Moreover, other substances have been used for the same purpose, such as ozone, organic acids, peroxyacetic acid, hydrogen peroxide, electrolyzed water, and calcium-based solutions [21][22][23][24][25][26].

Physical alternatives, such as ultraviolet light C, low-temperature storage, modification of atmosphere, and ultrasound or high pressure inert gas, to maintain quality and prolong shelf- life, have also been used [4]. As the cutting operations are unavoidable for fresh-cut fruits and vegetables, and the risk of microbial growth is possible, the avoidance of food-borne pathogen contamination is necessary without the production of potentially toxic substances. Nowadays, chemical compounds that are used for fresh-cut fruit and vegetable preservation are not preferable for consumers when they are eating fresh-cut fruits and vegetables, as they prefer healthier, more natural, safer, and non-chemically contaminated foods [6].

Food preservation with the help of natural antimicrobial agents could be a very promising technique, playing an important role in maintaining food quality and safety [27]. Food biopreservation is an alternative and novel method of preservation with increasing special interest from the consumers [22][28]. Biopreservation can extend the shelf life of fresh-cut fruits and vegetables by the use of safe, natural, or controlled microflora, and non-toxic biologically active compounds [29], enhancing their safety [30]. Biopreservation can help the production of fresh-cut fruits and vegetables, with increased safety, excellent nutrition, overall quality, and improved shelf life through the use of lactic acid bacteria (LAB).

3. Data, Model, Applications and Influences

3.1. Lactic Acid Bacteria

The use of LAB play a dominant role in the fermentation of both food and feed [31], with health and nutritional benefits, and a very long history and safe use after consumption of fermented foods and beverages [32]. Taste and texture are the main (quality) characteristics of fermented foods that are enhanced with the addition of LAB [33]. Dairy products, fermented fruits and vegetables, meat-based products, and fermented beverages are the main fermented foods that involve LAB [34][35][36]. LAB exists in environments such as water, soil, sewage, plants, as well as in humans and animals [32]. In general, environments rich in available carbohydrates are ideal for the growth of LAB. Cavities of humans and animals are also favorable places for their growth [34]. LAB can be isolated from many raw fruits and vegetables, and then used against natural microbial populations [37].

LAB belong to different taxonomic groups of Gram-positive bacteria, with a common characteristic that produces lactic acid as the main (or sole) product during fermentation of carbohydrates [38][39]. They have rod- or coccus-shaped cells [40], do not form spores, and are anaerobic or microaerophilic and acid-tolerant organisms [41]. They are naturally present in several food products, from which can be isolated [42].

LAB are generally regarded as safe (GRAS) microorganisms by the United States Food and Drug Administration (FDA), and Qualified Presumption of Safety (QPS) by the European Food Safety Authority (EFSA). Their use in food biopreservation are considered an alternative for the prevention of the growth of pathogenic microorganisms [43][44], as their competitiveness against pathogenic microorganisms make them extremely ideal candidates for the development of bioprotective agents for fresh fruits and vegetables [45]. During biopreservation, either antimicrobial metabolites can be applied without the producing strain, or culture-producing antimicrobial metabolites can be added [46]. These starter cultures can be added, either as individual cultures or as multi-species consortia [47]. In the group of LAB bacteria, there are 6 families, 38 genera, and all belong to the *Lactobacillales* order, *Bacilli* class, and *Firmicutes* phylum.

Lactococcus, *Streptococcus*, *Lactobacillus*, *Pediococcus*, *Leuconostoc*, *Lactosphaera*, *Melissococcus*, *Microbacterium, Propionibacterium*, *Enterococcus*, *Carnobacterium*, *Tetragenococcus*, *Aerococcus*, *Alloiococcus, Oenococcus*, *Vagococcus*, *Dolosigranulum*, and *Weisella* are the most common genera that belong to LAB [48][49][50][51]. Among all the genes present in LAB, Lactobacillus consists of 261 species (March 2020), ranking it in the genus with the most members. The genus *Lactobacillus* has been reclassified into 25 genera, including the *Lactobacillus delbrueckii* group, *Paralactobacillus*, and 23 novel genera with the names *Holzapfelia*, *Amylolactobacillus*, *Bombilactobacillus*, *Companilactobacillus*, *Lapidilactobacillus*, *Agrilactobacillus*, *Schleiferilactobacillus*, *Loigolactobacilus*, *Lacticaseibacillus*, *Latilactobacillus*, *Dellaglioa*, *Liquorilactobacillus*, *Ligilactobacillus*, *Lactiplantibacillus*, *Furfurilactobacillus*, *Paucilactobacillus*, *Limosilactobacillus*, *Fructilactobacillus*, *Acetilactobacillus*, *Apilactobacillus*, *Levilactobacillus*, *Secundilactobacillus* and *Lentilactobacillus* [52]. The following are the most common species: *Lactobacillus acidophilus*, *L. plantarum*, *L. Casei*, *L. rhamnosus*, *L. delbrueckii bulgaricus*, *L. fermentum*, *L. reuteri*, *Lactococcus lactis*, *Lactococcus lactis cremoris*, *Bifidobacterium bifidum*, *B. infantis*, *B. adolecentis*, *B. longum*, *B. breve*, *Enterococcus faecalis*, *Enterococcus faecium* [51].

LAB produce a variety of antimicrobial compounds, such as organic acids (lactic, citric, acetic, fumaric, and malic acid), hydrogen peroxide, CO_2, diacetyl, ethanol, reuterin, acetaldehyde, acetoin, ammonia, bacteriocins, bacteriocin-like inhibitory substances (BLIS), and other important metabolites, which possess strong antagonistic activity against many microorganisms [53][54][55][56] (Figure 1). In addition, the antimicrobial effect of lactic acid bacteria is the result of competition with pathogenic microorganisms for nutrients [24].

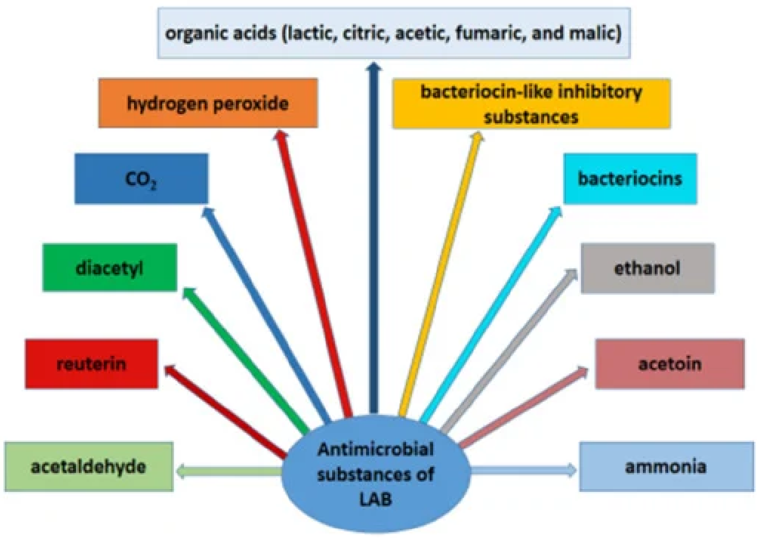

Figure 1. Antimicrobial substances produced by lactic acid bacteria.

Additionally, health-promoting properties have been linked with the presence of some strains of LAB and probiotics [57][58][59] as they have managed to reduce the risk of various diseases [60]. Probiotics have been identified as living microorganisms that have beneficial effects for humans and animals after adequate intake [61]. Probiotics have been used to prevent colon cancer [62], antibiotic-associated diarrhea, cholesterol reduction, lactose digestion [59], inflammatory bowel disease, breast cancer, and ulcerative colitis [63]. The genus *Lactobacillus* is one of the most widely used probiotics available on the market [60]. Probiotic bacteria do not live apart from the environment, but interact with the host, forming cooperative communities called biofilms [62].

In exception for their antimicrobial activity, LAB also have antifungal activity, which is of great interest, both against mycotoxigenic fungi and fungal mycotoxins, showing their potential by inactivation, removal, or detoxification processes [64][65][66]. The antifungal activity of LAB has prolonged the shelf life of fresh vegetables [67] and fruits [68].

4. Conclusions

After harvesting fruits and vegetables and during storage and transportation, their sensorial, nutritional and sensorial quality decreases due to high moisture content, microbial growth, environmental factors, maturity and senescence. Considering their very short shelf life, fruits and vegetables need immediate post-harvest care to increase it. Biopreservation using LAB has been gaining interest, since they are classified as "generally recognized as safe" and have shown antimicrobial capacities; additionally, it is considered an environmentally friendly method. The use of a variety of antimicrobial compounds produced by LAB promises to be an effective technique to guarantee safety and to extend the useful life of fruits and vegetables during post-harvest period. The use of LAB in preservation of fresh fruits and vegetables, need further research. The ecological role of LAB is still under investigation in nature, but they can be considered as a sustainable option for preservation of fresh fruits and vegetables.

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