

## Minimally processed fruits with added probiotics: A review

### Frutas minimamente processadas com adição de probióticos: Uma revisão

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#### Resumo

Os probióticos podem ser definidos como microrganismos vivos que, quando utilizados nas quantidades adequadas, conferem benefícios à saúde do hospedeiro. Os probióticos são bem conhecidos e bem aceitos pelos consumidores, mas estão presentes principalmente em produtos lácteos, sendo uma barreira para consumidores que possuem intolerância à lactose ou que são alérgicos às proteínas do leite. Nesse sentido, as matrizes vegetais são adequadas para hospedar microrganismos probióticos visando incrementar as características funcionais dos vegetais minimamente processados. Desta forma, esse trabalho faz uma revisão dos principais estudos que mostram o potencial da adição de probióticos em frutas minimamente processadas. Além disso, são discutidas as diferentes formas de adição de probiótico em matrizes vegetais. Em paralelo, a revisão apresenta a viabilidade dos probióticos em frutas minimamente processadas, os desafios encontrados e a melhor estratégia para a incorporação destes microrganismos em matrizes vegetais. As pesquisas disponíveis indicam que as propriedades intrínsecas dos vegetais contribuem para uma associação eficaz dos probióticos. Portanto, a possibilidade de utilizar essas matrizes como carreadores de cepas probióticas é uma oportunidade de fornecer aos consumidores novos alimentos probióticos que podem fazer parte de uma dieta variada garantindo uma ingestão regular destes microrganismos.

**Palavras-chave:** Microrganismo. Matrizes vegetais. Desafios. Viabilidade.

## Abstract

Probiotics can be like microorganisms that, when used for the health of living animals, confer health benefits. Probiotics are well known and well accepted by consumers, but they are mainly in dairy products, being a barrier to consumers who are lactose intolerant or allergic to milk proteins. In this sense, plant matrices are suitable to host probiotic microorganisms to increase the functional characteristics of minimally processed vegetables. In this way, this work reviews the main studies that show the potential of adding probiotics to minimally processed fruits. In addition, different ways of adding probiotics to plant matrices are discussed. In parallel, the review presents the viability of probiotics in minimally processed fruits, the challenges encountered and the best strategy for the incorporation of these microorganisms into plant matrices. Available research indicates that the intrinsic properties of vegetables contribute to an effective association of probiotics. Therefore, the possibility of using these matrices as carriers of probiotic strains is an opportunity to provide consumers with new probiotic foods that can be part of a varied diet, ensuring a regular intake of these microorganisms.

**Keywords:** Microorganism. Vegetable matrices. Challenges. Viability.

## 1. Introduction

An important property of the intake of nutritional fruits and vegetables and good nutritional sources, as they have beneficial benefits for human health, in addition to being a diet of minerals, vitamins, and food nutrients (Slavin; Lloyd, 2012). The Food and Agriculture Organization of the United Nations (2015) recommends eating at least 400 grams of fruits and vegetables a day.

The world has demanded ready-to-eat products and minimally processed products have followed this demand. Consumers prefer to purchase sanitized, cut, and ready-to-eat fruits and vegetables (Assis; Britto; Forato, 2009; SENAI, 2016). Various denominations are given to minimally processed fruits and vegetables, such as those undergoing physical changes and without compromising their fresh state (IFPA, 2002). Minimally processed vegetables are those that are cut and ready to eat without losing their fresh appearance (Fonseca; Soares; Freire junior, 2009; Moretti, 2007). Or even minimally processed products are those that have been subjected to one or several processes such as washing, peeling, cutting, and centrifuging, maintaining their characteristics (SENAI, 2016).

Probiotics are defined as live microorganisms that, when administered in adequate amounts, confer a health benefit to the host (Hill et al., 2014). In this sense, plant matrices are suitable for hosting microbial populations such as probiotic strains (Flash, 2018), which can increase the functional characteristics of minimally processed foods.

The objective of this work is to present studies that show the addition of probiotics in minimally processed fruits, their viability, the challenges encountered and their acceptance by consumers.

## 2. Probiotic in minimally processed vegetables

### 2.1 Minimally processed fruits with added probiotics

The main genera of lactic acid bacteria used for addition to vegetables are *Lactobacillus* spp., *Leuconostoc* spp., *Bifidobacterium* spp., *Streptococcus* and *Enterococcus*. It is necessary that probiotic cultures survive the gastrointestinal tract reaching the colon, where they will colonize the intestinal epithelium with a minimum count between  $10^6$  and  $10^7$  CFU/mL or grams of product (Montanari et al., 2020). Minimally processed fruits can be carriers of probiotic microorganisms and serve consumers who are part of groups restricted to dairy products or who choose not to consume them (Rasika et al., 2021). Several fruits are potential carriers of probiotic microorganisms because of their nutritional composition, high carbohydrate content, as they are sources of vitamins, minerals, and fiber. Soluble fibers are substrates for probiotic microorganisms that, when fermenting, produce short-chain fatty acids (Bellis; Sisto; LaVermicocca, 2021).

Polysaccharides and the high fiber content of certain fruits are essential for the protection of probiotic bacteria. In addition, another factor that favors fruit and other vegetables as carriers of probiotics is the tissue structure, specifically the intertwining of cells and the space between them. This structure allows the adhesion of microorganism cells, and contributed to protection against external factors, such as temperature, acidity, intestinal motility, and agitation (Lillo-Pérez et al., 2021).

## 2.2 Challenges of adding probiotics to plant matrices

The addition of probiotics in plant matrices faces several challenges to deliver the necessary amount to the colon to exert the so-called minimal therapeutic effect. The viability of these microorganisms depends on factors such as the type of strain that will be inoculated, the level of available oxygen, temperature, whether there is the presence of antimicrobial compounds in the plant matrix and the pH, as many fruits have low and high pH. concentration of organic acids that can negatively affect the viability of probiotics. Other challenges are those related to the passage through the gastrointestinal tract, such as the low pH of the stomach, the high concentrations of bile salts in the duodenum, as well as intestinal motility (Szutowska, 2020).

In addition, the processing and storage methods can also affect the survival of microorganisms, such as mechanical, thermal, osmotic, oxidative stresses, and low water activity can occur in these stages (Lillo-Pérez, 2021). But despite the challenges, minimally processed fruits favor the viability of probiotics, as shown by some more recent works in Table 1.

**Table 1 – Probiotic strains and their viability in some minimally processed**

Probiotic Strain	Minimally Processed Fruit	Survival (Log CFU/g <sup>-1</sup> )	References
<i>B. coagulans</i>	Banana leather (Dehydrated mashed banana leaves)	>7,6	Niro et al. (2022)
<i>L. rhamnosus</i> <i>B. animalis</i>	Diced apple	7,8 8	Alvarez et al. (2021)
<i>L. casei</i> , <i>B. animalis</i>	Blueberries	>7,5 Log	Bambace; Alvarez; Moreira (2021)
<i>B. coagulans</i>	Dehydrated strawberry halves	≅ 8	Oliveira et al. (2021)
<i>L. casei</i>	Dehydrated apple slices	10 <sup>7</sup>	Valerio et al. (2020)
<i>B. coagulans</i>	Dry date paste	7,88	Marcial-Coba et al. (2019)
<i>L.rhamnosus</i> <i>L. fermentum</i>	Melon	8 7,8	Russo (2015)

## 2.3 Ways of adding probiotics to minimally processed fruits and acceptance by consumers

Minimally processed foods were introduced into people's daily lives to facilitate their consumption, precisely because of their practicality in everyday life. In Brazil, these minimally processed foods were introduced in the 1990s, where industries were attracted by new trends in the food market, as there was a need to propose greater ease in consuming such foods (Carvalho et al., 2016). The minimal processing of fruits can be called any fruit that has physical alterations but maintains its natural and fresh state, presenting itself sanitized without peel, seeds, or stems that are

ready for consumption. However, minimally processed fruit salad stands out for being easy to consume by consumers who want to adapt their daily routine to a healthier diet (Silva et al., 2018).

Probiotics are live microorganisms that confer benefits to human health when administered in adequate amounts, usually by improving or restoring the intestinal microflora (FAO, 2016; Leber et al., 2018). A technique widely used for the application of probiotics added to plant matrices is the vacuum impregnation technique and the immersion technique (Doğan; Tekiner; Demirkesenbiçak, 2019). Vacuum impregnation technology has great prospects for application in the production of functional foods, including vegetables added with probiotic bacteria, this technique uses pressure gradients to incorporate functional components into the structural matrix of porous foods, without substantially modifying their sensory properties (Oliveira, 2014). Thus, the vacuum impregnation technique aims to incorporate functional ingredients into foods through the incorporation of physiologically active compounds, such as vitamins, minerals, antioxidants, enzymes, pH regulators, antimicrobials, dietary fiber, probiotics, prebiotics and symbiotics, improving the sensory and nutritional characteristics of food and increasing its shelf life (Hironaka et al., 2011).

Another alternative for the incorporation of probiotics in plant matrices is the immersion technique, which is widely used in porous products such as minimally processed vegetables. Penetration occurs by capillarity, causing a portion of the liquid to be retained in the material, favoring the fixation of the compounds of interest (Oliveira, 2014).

The dipping technique to add probiotic microorganisms was used in minimally processed fruit salad by Martins (2012). In this work, 3 types of microorganisms were added, where counts of *L. plantarum*, *L. acidophilus* and *L. rhamnosus* above  $10^8$  CFU·g<sup>-1</sup> were obtained during the product stored at 8°C for 5 days.

Consumers' search for a healthy diet that brings health benefits, in addition to basic nutrition, has driven the food industry to develop new products and use new manufacturing technologies to develop products that contain functionally active ingredients, such as probiotics. In the face of new requirements, there has been a significant increase in people who have chosen to consume minimally processed products with the addition of active ingredients, such as minimally processed fruits with the addition of probiotics in their matrix to obtain a more balanced healthy diet (Oliveira, 2014).

### 3. Conclusion

Available research indicates that the intrinsic properties of plant matrices can be successfully used and improved, with an effective association with probiotics. The possibility of using these matrices as carriers of probiotic strains is an opportunity to provide consumers with new probiotic foods that can be part of a varied diet, ensuring a regular intake of probiotic bacteria.

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