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Fresh fruits and vegetables—An overview on applied methodologies to improve its quality and safety

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ABSTRACT

The consumers' demand for fresh fruits and vegetables has increased in recent years. These foods may be consumed raw or minimally processed, and therefore can be a vehicle of several pathogens. The microorganisms most frequently linked to produce-related outbreaks include bacteria (*Salmonella* spp., *Listeria monocytogenes*, *Escherichia coli*, and *Shigella* spp.), viruses and parasites.

There are many traditional technologies to reduce/eliminate the microorganisms present in food products. However, further research on this topic is still required, since none of the methods reported can control all the parameters necessary to achieve produce with an extending shelf-life, without compromising its quality.

In this paper, an analysis of the alternative and traditional methodologies is made, pointing out the significant advantage and limitations of each technique.

Industrial relevance: The significant increase in the incidence of foodborne outbreaks caused by contaminated minimally processed produce in recent years has become of extreme importance. The extensive knowledge of gentle (non-thermal) processes to enhance safety, preservation and shelf-life of these products is crucial for the food industry.

This manuscript presents non-thermal processes that have shown efficient microbial reductions on fresh produce and highlights some of their challenges and limitations.

Contents

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1. Introduction

Fruits and vegetables are essential components of the human diet and there is considerable evidence of the health and nutritional benefits associated with their consumption (Abadias, Usall, Anguera, Solson, & Vinas, 2008; Warriner, Ibrahim, Dickinson, Wright, & Waites, 2005). Due to the presence of high levels of micronutrients and fibers, their consumption is recommended by many organizations (World Health Organization—WHO, Food and Agriculture Organization—FAO, United States Department of Agriculture—USDA and European Food Safety Authority—EFSA) to reduce the risk of cardiovascular diseases and cancer (Allende, McEvoy, Luo, Artes, & Wang, 2006a; Ragaert, Verbeke, Devlieghere, & Debevere, 2004; Su & Arab, 2006; Warriner, 2005).

As a response to consumers' demand for healthy, fresh-like and easy to prepare products, conjoint with consumer lifestyle changes, a wide variety of minimally processed fruits and vegetables (MPFVs) has been developed (Allende et al., 2006a; Froder et al., 2007; Scolari & Vescovo, 2004; Tournas, 2005).

Minimal food processing techniques constitute non-thermal technologies with guarantee of food preservation and safe standards as well as maintaining, as much as possible, the fresh-like characteristics of fruits and vegetables (Allende, Tomas-Barberan, & Gil, 2006b; Allende et al., 2006a). Minimally processed products aim to extend the product shelf-life of 5–7 days at 4 °C, while ensuring food safety and maintaining nutritional and sensory quality (Cliffe-Byrnes & O'Beirne, 2002).

The marketing of these types of foods continues to rise mainly due to their freshness, economic handling and attractive presentation (Little & Gillespie, 2008). They constitute a suitable meal for today's lifestyles, because they do not need preparation and provide a great variety of vitamins, minerals and other phytochemicals, which are important in human health (Froder et al., 2007).

Fruits and vegetables require proper handling, preparation and storage in order to take full advantage of their nutrients. When these products are minimally processed, they are submitted to unit operations that include selection, cleaning, washing, trimming, peeling, cutting and shredding, sanitizing and packing. As these operations do not assure the absence of microorganisms, minimally processed fruits and vegetables, require refrigeration as a primary means of preservation (Froder et al., 2007; Tournas, 2005).

Consumers are becoming more aware about the limitations of commonly sanitizing techniques and are looking for safe food products that suffer minimal processing, with high quality retention. To satisfy these requirements, food industry is currently studying non-thermal techniques such as ozone based treatments, ultraviolet radiation, pulsed light, cold plasma, ultrasounds and novel packaging practices. All these technologies have a great potential in the field of minimally processed foods. However, there is a lack of available information about advantages and limitations of these technologies, when applied to food processing. The efficiency of the processes depends directly on the combination food/contaminant/process and important fresh characteristics to maintain.

This paper gathered information about these novel technologies and the ones commonly used, pointing out their most relevant advantages and limitations. An overview of produce microbiota patterns and outbreaks related to fruits and vegetables is presented, showing the importance of choosing an effective method for microbial inactivation on these products.

2. Produce microbiota

Fresh fruits and vegetables, including plant components as leaves, roots, bulbs and tubers, have different morphology and metabolic functions and consequently provide diverse ecological niches to microorganisms (Brackett, 1999; Burnett & Beuchat, 2000; Ponce, Roura, del Valle, & Fritz, 2002). The presence and number of microorganisms differ depending on the type of produce, agronomic practices, geographical area of production, and weather conditions before harvest. Harvest, transportation and further processing and handling of produce can greatly influence the microbiota pattern (Ahvenainen, 1996; Olaimat & Holley, 2012).

The number and type of microorganisms found on fresh produce are highly variable. Mesophilic bacteria are around 10^3–10^9 CFU/g in raw vegetables after harvest, depending on the produce and the growing conditions (Oliveira et al., 2010; Zagory, 1999). Gram-negative bacteria dominate the microflora associated with most vegetables, whereas yeasts and moulds are often the majority microflora of raw fruits (Burnett & Beuchat, 2000; Tournas, 2005). The microflora of vegetables and fruits is made up largely of *Pseudomonas* spp., *Erwinia herbicola*, *Flavobacterium*, *Xanthomonas*, and *Enterobacter agglomerans* as well as various moulds, *Alternaria*, *Penicillium*, *Fusarium* and *Aspergillus*. Lactic acid bacteria, such as *Leuconostoc mesenteroides* and *Lactobacillus* spp., are also commonly found. Finally, yeasts such as *Torulopsis*, *Saccharomyces* and *Candida* are part of dominant microorganisms, mostly on fruits because of their high sugar content (Caponigro et al., 2010; de Azeredo et al., 2011; Pianetti et al., 2008). *Pseudomonas* spp. normally dominates and may make up 50–90% of the microbial population on many vegetables (Arvanitoyannis & Stratakos, 2010; Nguyenthe & Carlin, 1994; Zagory, 1999).

3. Fruit and vegetable contamination

The natural microflora of raw fruits and vegetables is usually non-pathogenic for humans and may be present at the time of consumption (Ahvenainen, 1996; Food & Drug Administration, H. H. S., 2008). However, during growth, harvest, transportation and further processing and handling, the produce can be contaminated with pathogens from human, animal, or environmental sources (Ahvenainen, 1996; Brandl, 2006; Froder et al., 2007; Sánchez, Elizaquível, & Aznar, 2012). During peeling, cutting and shredding, the surface of the produce is exposed