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Novel Decontamination Technologies for Fresh-cut Industry

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Introduction

The European fresh-cut market is a fast growing food sector and the consumption of fresh-cut salads or fruits is further increasing due to the key driver convenience and the public awareness to health benefits. According to the Rabobank Group, the value of the European fresh-cut market was about 3.4 billion € in 2008 and the expected growth is more than 4% annually from 2011, both in volume terms and overall value [1].

However, also the number of outbreaks by fresh-cut produce has been rising in last decades. In particular, leafy greens can be highly contaminated and product contamination is very difficult for consumers to combat, as produce is often served raw [2]. According to the Centers for Disease Control and Prevention (CDC), leafy greens have caused 363 food-borne illness outbreaks in more than 13,500 reported cases in the United States since 1990. This was also the reason why the leafy greens were atop the 10 most dangerous foods regulated by the FDA [3]. Outbreaks from fresh-cut produce occur where these popular food items are consumed and the frequency of produce-associated outbreaks in Europe appears to be similar to the US. Recent examples are a large-scale EHEC O104:H4 outbreak in Germany in 2011 with approximately 3000 cases and more than 50 deaths, which was probably caused by contaminated fenugreek seeds as well as a multistate outbreak of Listeriosis in the United States (146 cases, 30 deaths) linked to whole cantaloupes [4,5]. Relevant for food safety are foodborne pathogens, especially psychotropic bacteria like Listeria monocytogenes, which can grow in the cooling chain and species of the family Enterobacteriaceae like *Salmonella enterica* or *Escherichia coli* [6,7]. Furthermore, the emergence and spread of multi resistant foodborne bacteria like methicillin-resistant Staphylococcus aureus (MRSA) or Enterobacteriaceae producing extended-spectrum β-lactamases (ESBLs) underlines the necessity of efficient hygienic concepts.

Initial contamination of the leafy greens can occur on the farm by contact with manure, contaminated water or also due to poor handling practices during harvest and the postharvest processing. Because excluding the risks of pre-harvest contamination seems to be impossible, disinfection and cleaning became two key operations of food processing in assuring the safety and quality of food products for a pre-defined period of shelf life. Current methods used for disinfection and cleaning of fresh-cut salad rely on rigorous washing processes and the use of high amounts of chemicals mainly chlorine. Eliminating the need of chemicals will deliver substantial benefits in terms of the sustainable use of natural resources, preventing/minimizing environmental pollution and mitigating health hazards associated with environmental pollution, chemical residues in foods and harmful by-products in the water. Emerging sterilization technologies like non-thermal gas plasma and pulsed light could be alternative approaches for the non-chemical disinfection of fresh produce.

Pulsed light and cold gas plasma

Pulsed UV light is an upcoming technology and a suitable method for the decontamination of surfaces. The main piece of equipment required, besides a power supply and the pulse configuration device, is an inert gas flash lamp (e.g. xenon) which emits a continuous broad-spectrum of white light comprising wavelengths from 200 nm (UV) to 1000 nm (near infrared) and having a maximum at 450 nm. The emission spectrum is similar to natural sunlight, but the intensity of the pulsed light is about 20,000 times higher. The very short treatment times in combination with the high efficiency has qualified the pulsed light technology as a rapid, low-energy and non-thermal method for the decontamination of surfaces (e.g. packaging materials). Pulsed light systems are very efficient in inactivation of microorganisms on surfaces: Dunn et al. [8] have reported that inactivation of *A. niger* spores by more than seven log-cycles can be achieved by a few light pulses (1 J/cm²). Pulsed light treatment of food has been approved by the FDA (1996) under the code 21CFR179.41 and there are some publications concerning the treatment of vegetables with lab systems available [9,10] which are proving the principal feasibility to inactivate microorganisms in vitro, but its effect on the food properties is still under investigation.

Cold gas plasma treatment is another innovative technology for the non-thermal inactivation of microorganisms on surfaces. By using the main inactivation mechanisms such as UV radiation, chemically reactive species and charged particles, both microorganisms and biomolecules (e.g. endotoxins, prions) can be efficiently destroyed. Cold gas plasmas are capable of inactivating a broad range of microorganisms including gram-positive and gram-negative bacteria, bacterial endospores, fungi, and viruses on different surfaces within few seconds [9]. The high efficiency and the versatility of the plasma technology (direct and remote plasma) make it suitable for various applications in the food and medical fields. However, the sterilization of food surfaces by gas plasma is still relatively unexplored and there are just a few publications in relation to the treatment of vegetables, egg shells or meat [11,12]. Nevertheless, current research projects are focusing on this topic (e.g. German project FriPlas, European project SAFE-BAG (FP7-SME-2011, 285820)).

Generally, in developing environmentally friendly alternative decontamination methods, it is necessary to take into account the compatibility and cost factors, impact on product quality (nutritional, sensory, chemical, toxicology), interactions with the food, environmental impact and also the regulatory provisions. According to Fonseca [13], the efficacy of sanitizers for produce depends also

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on the type of product, the microorganisms present (type and their distribution pattern) and the application system [13]. Utilization of sequential treatments that have different modes of actions seems to be an interesting approach, provided that the costs can be kept at affordable levels for SMEs in this sector. This indicates that the development of a new realistic process for fresh-cut industry has to be well balanced between research on the one side and practical application on the other side.

Conclusion

Physical technologies like cold gas plasma and pulsed light could be promising alternatives for reducing the microbiological risk associated with fresh-cut produce. Both technologies have proven their efficiency for the fast inactivation of microorganisms on various surfaces, but further research must be implemented to get information about their effect on the sensorial and nutritional components of foodstuff as well their efficiency under realistic conditions.

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