INFLUENCE OF ULTRAVIOLET LIGHT TREATMENT ON SURFACE DECONTAMINATION OF FRESH-CUT FRUITS

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Abstract: Consumer demand for high quality minimally processed fruit with natural flavour and fresh appearance has been greatly increased in recent years. Besides, fresh-cut fruits are broadly growing segments in retail establishments. However, fresh-cut processing includes unit operations such as peeling, trimming, cutting and slicing that alter the integrity of fruits' tissues and can induce wounding stress which promotes microbial growing of natural microbiota. Pathogens may form part of fruits' natural microbiota, so that this lead to a potential safety problem. Physical processing techniques such as ultraviolet (UV) light treatment meet these requirements. The aim of this paper was to investigate the available literature data and provide a general review of the application of UV light treatment for the decontamination, preventing diseased and enhancing the shelf life and quality of fresh-cut fruits.

Keywords: ultraviolet light, fresh-cut fruits and vegetables, decontamination, extended shelf-life.

Introduction

Modern consumer shows a growing interest in the role of food and an increasing health consciousness for maintaining and improving consumer health and human well-being (Olivas & Barbosa-Canovas, 2005). Therefore tasty, safe, healthy, natural, organic and fresh foods which are produced in an environmentally friendly manner with sustainable methods and small carbon footprint are requested. In addition to their nutritional and sensory properties, foods are directly recognised as active and protective agents.

Fresh foods, e.g. fruits and vegetables, often referred to as "green" foods are important components of a healthy and balanced diet, being able to decrease the risk of cardiovascular diseases and cancer (WHO/FAO, 2004; Allende et al., 2006). Whether eaten fresh or cooked they should be sound, clean and as free as possible of microorganisms and pesticides.

In the last years, the consumption of fresh fruits and vegetables has continued to grow rapidly as a result of increased consumers' awareness of their health benefits. However, it remains below the recommended daily intake in many countries, due to barriers such as complacency and lack of willpower to change the diet (Ragaert et al., 2004).

Among all foods, fresh-cut fruits and vegetables stand out as convenient novel foods that fit the many needs of a modern lifestyle as they combine technical content with an innovative food concept (Olivas & Barbosa-Canovas, 2005).

The International Fresh-Cut Association (IFCA) defines fresh-cut products as wholesome, convenient and ready-to-use fresh fruits and vegetables that are physically altered from their original form, but remaining in a fresh state. These fruits and vegetables have been trimmed, peeled, washed and cut into 100% usable product that is bagged or pre-packaged to offer consumers high nutrition, convenience and value while still maintaining freshness (http://www.creativew.com/sites/ifpa/about.html).

In particular, fresh-cut fruits attract consumers because they are fresh, nutritious, ready-to-eat and low priced. As a consequence, a wide assortment of minimally processed fruits has been developed to meet the consumer's needs for "quick" and convenient products and to benefit from the health image of fruits (Bello-Perez et al., 2012).

Minimally processed fruits contain living tissue that has undergone minor changes from its fresh state because the cutting, splicing, peeling, etc. operations form small lesions in the tissue. These lesions determine enzymatic browning, texture decay, rapid microbial growth, weight losses and undesirable volatile production, thus reducing highly the shelf life. Therefore, fresh-cut fruits are characterised by a shorter shelf life than their whole counterparts due to higher susceptibility to microbial spoilage, increased respiration rate and ethylene production, which are stimulated by wounding of the tissue (Chien et al., 2007). These are responsible for safety and quality depletion of the product, which translate not only in food spoilage but also in risk of foodborne illness (Rico et al., 2007). For these reasons, even few days of fresh cut fruits shelf life extension could represent a remarkable advantage for the companies operating in the sector.

The risk involved with the consumption of fresh fruit and vegetables could be minimised either by reducing or by eliminating external surface contamination. This is carried out through several selective methods such as washing with water, washing with disinfectant solutions, modified atmosphere packaging, low temperature storage, edible films, ultraviolet light etc.

Ultraviolet light

Nonionizing, germicidal, artificial ultraviolet (UV) light is a nonselective physical method used for decontamination and/or sterilisation of food surfaces and surface of materials in contact with food. Unlike chemical sanitizers, UV-C does not leave a residue, and does not require extensive safety equipment (Yaun et al., 2004).

UV-C (λ = 200-280 nm) is a segment of UV spectrum directly lethal to microorganisms, hence the term "germicidal". UV-C cross DNA pyrimidine bases of cytosine and thymine, impairing formation of hydrogen bonds with the purine base pair on the complimentary strand of DNA and thus reproduction of microorganisms (Bintsis et al., 2000; Shama, 2006). It has also been proved to cause significant damage in the cytoplasmic membrane integrity and in the cellular enzyme activity (Schenk et al., 2011).

However, the germicidal action of UV-C light is strongly dependent on the natural resistance to UV-C of the microorganisms. Shama (2006) has shown that microorganisms differ greatly in the UV doses required for inactivation. Another important factor of survival is the surface on which microorganisms are attached. Gardner & Shama (2000) have shown that surface "topography" plays a major role in determining survival following exposure to UV-C. Microorganisms present on a surface that may be considered smooth are more susceptible to the effects of UV than the microorganisms present on a surface containing crevices inside which they might be shielded from the lethal effects of UV-C. The germicidal effect occurs over relatively short time that is essentially limited to the time of exposure of the microorganism to the UV source. The exposure times typically range from fractions of a second to perhaps tens of seconds.

Inactivation of microorganisms on fresh-cut fruit surfaces with UV light

The effectiveness of UV-C light exposure on safety and quality of fresh-cut fruits was investigated with reference to different fruits. These researches indicated that UV-C light is effective in reducing natural microbiota and extending the shelf-life of fresh-cut products such as apple slices (Gómez et al., 2010), grapefruit (D'hallewin et al., 2000), pear (Schenk et al., 2008) and pineapple (Pan et al., 2012). Similar results were obtained for sliced mangoes (Gonzalez-Aguilar et al., 2007), watermelon cubes (Artés-Hernández et al., 2010) and many other fruits (Table 1). In these studies, UV-C light was applied during cutting operations and before packaging.

Lamikanra et al., 2005 compared the effect of processing cantaloupe melon under UV radiation on storage properties of the cut fruit with post-cut UV-C fruit treatment. The results indicated that fresh-cut pieces of melon than treated with UV light had lower populations of aerobic mesophilic and lactic acid bacteria compared to control and post-cut-treated pieces. Moreover, post-cut application of UV radiation improved shelf life, while cutting fruit under UV light further improved the quality of the product (Lamikanra et al., 2005).

Fonseca & Rushing (2006) reported the influence of UV-C light (1.40-13.70 kJ/m^2 at 254 nm) on the quality of fresh-cut watermelon. They showed that exposing packaged watermelon cubes to UV light at 4.1 kJ/m^2 produced more than a 1-log reduction in microbial populations without affecting juice leakage, colour, and overall visual quality.

Schenk *et al*. (2008) investigated the microbicidal effect of UV-C light (λ = 253.7 nm, dose range between 0 and 87 kJ/m^2) on pear slices with and without peel against *Listeria innocua* ATCC 33090, *L. monocytogenes* ATCC 19114 D, *Escherichia coli* ATCC 11229, and *Zygosaccharomyces bailli* NRRL 7256 used as individual strains. Then strain cocktails of *Listeria*: *L. innocua* ATCC 33090, *L. innocua* CIP 8011, *L. welshimeri* BE 313/01, *L. monocytogenes* (ATCC 19114, ATCC 33090), and yeasts: *Z. bailli* NRRL 7256, *Z. rouxii* ATCC 52519, and *Debaryomyces hansenii* NRRL 7268 were used for inoculation. Inoculated pear slices were treated with UV-C then log reductions of microbial populations were determined. Overall, as the UV dose was increased by increasing the time of exposure, better inactivation was obtained for all microbial species. Great log reductions rated were obtained at UV-C doses smaller than 15 kJ/m^2. The UV-C treatment was more effective for pear slices without peel. Thus, the inactivation ranges between 2.6 and 3.4 log cycles for these samples and 1.8 and 2.5 log cycles for pear slices with peel after treatments lasting 20 min, corresponding to 87 kJ/m^2 UV-C dose.

López-Rubira et al. (2005) found inconsistent results regarding the effect of UV-C on microbial growth in fresh cut pomegranate arils stored up to 15 d at 5°C, only some UV doses reducing mesophilic, psychrotropic, lactic acid bacteria and enterobacteriaceae counts.

Conclusions

Fresh-cut fruits are highly susceptible to microbial spoilage. This can be avoided with the application of surface treatments. The treatment of their surface has to be as gentle as possible for keeping the integrity and the freshness of fruits and vegetables. The use of UV light treatment proved to be effective at reducing microbial loads of pathogens on fresh-cut fruits.

Table 2. Summary of the study results on the inactivation of microorganisms on fresh-cut fruit surfaces with UV light

Fresh-cut fruit (Cultivar)	UV light treatment conditions	Inactivation result/(log reduction)	References
Apple (*Malus domestica* Borkh, cv. Pink Lady)	UV-C 1.2, 6.0, 12.0 and 24.0 kJ/m^2	– 1-2 log reduction in total viable counts – UV-C dose of 1.2 kJ/m^2 resulted in apple slices much more stable than controls	Manzocco et al., 2011b
Apple (*Malus pumila*, var. Golden Delicious) slices of 10 g	UV-C, 0.5 and 1.0 kJ/m^2 Storage period up to 15 days at 4°C	– UV-C dose of 1.0 kJ/m2 was the most effective treatment in reducing *E. coli*, *L. innocua* and *S. enterica* during the storage period	Graça et al., 2013
Apple (*Malus pumila*, var. Granny Smith) discs (d=3 cm, δ=0.6 cm)	UV-C, 253.7 nm Dose: 5.6, 8.4 and 14.1 kJ/m^2 Duration: 10, 15 or 25 min	– Reduction of the initial microbial load of the product – Reduction of *E. coli*, *L. innocua* and *S. cerevisiae* inoculated on apple discs	Gomez et al., 2010
Cantaloupe melon (*Cucumis melo* L.)	UV-C Storage at 10°C	– UV-C was effective in reducing yeast, mould and *Pseudomonas* spp. populations	Lamikanra *et al.*, 2005
Melon (*Cucumis melo* L. var. reticulates) cubes	UV-C 0, 1.2, 6.0 and 12.0 kJ/m^2 up to 10 min Storage at 6°C	– 2 log reductions for both total viable count and Enterobacteriaceae – Decreased melon leakage due to a thin dried film formation	Manzocco et al., 2011a
Pear (*Pyrus communis* L.) fresh-cut	UV-C, 253.7 nm 0-87 kJ/m^2	– Great log reduction rates at doses between 0 and 15 kJ/m^2 – Effectiveness of UV-C against *L. innocua*, *L. monocytogenes*, *E. coli*, *Z bailli*, *D. hansenii*	Schenck et al., 2008
Pear (*Pyrus communis*, cv. William)	UV-C, 253.4 nm Dose: 3.7 kJ/m^2 Duration 450 s	– Effectiveness in inactivation of spoilage microorganisms	Garcia Loredo et al., 2013
Pomegranate arils (*Punica granatum* cv. Mollar of Elche)	UV-C 0.56 - 13.62 kJ/m^2 Stored up to 13 or 15 days at 5°C	– Some of UV-C treatments reduced mesophilic, psychrotrophic, lactic acid and *Enterobacteriaceae* counts	López-Rubira et al., 2005
Watermelon cubes	UV-C 4.1 kJ/m^2	– UV-C reduced the microbial population by less than 1 log CFU/g by the end of shelf-life	Fonseca & Rushing, 2006
Watermelon cubes (*Citrullus lanatus* cv 'Fashion')	UV-C, 1.6, 2.8, 4.8 and 7.2 kJ/m^2 Storage 11 d. at 5°C Initial microbial load 2.4 log CFU/g	– Maximum reduction of 2 log CFU/g for 7.2 kJ/m^2 – Reduction of 1 log CFU/g for the lower dose (1.6 kJ/m^2)	Artés-Hernández et al., 2010

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