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Moderate UV-C pretreatment as a quality enhancement tool in fresh-cut Bimi® broccoli

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ABSTRACT

The effects of several UV-C pre-treatments (1.5, 4.5, 9.0 and 15 kJ m^{-2}) on changes in physiological, sensory and microbial quality and health promoting bioactive compounds over 19 days at 5 and 10 °C of fresh-cut Bimi® broccoli were studied. Non-irradiated samples were used as controls. Bimi® broccoli (*Brassica oleracea* Italica Group × Alboglabra Group) is characterised by a long stem with a small floret with a mild and sweeter flavor than conventional varieties well adapted for fresh-cut purposes. Low and moderate UV-C doses (1.5 and 4.5 kJ m^{-2}) had inhibitory effects on natural microflora growth. In relation to sensory quality, all treatments resulted in a shelf-life of 19 and 13 days at 5 and 10 °C respectively with the exception of 15 kJ UV-C m^{-2} treated samples which resulted in a shorter shelf-life. These doses immediately increased total polyphenols contents up to 25% after 19 days at 5 °C compared to the initial value. All the hydroxycinnamoyl acid derivates were immediately increased after UV-C treatments, with values 4.8- and 4.5-fold higher for 4.5 and 9.0 kJ UV-C m^{-2} treated samples respectively over the control. Changes in phenolic compounds were highly influenced by the storage temperature throughout shelf-life. Total antioxidant activity generally followed the same pattern: the higher the UV-C doses, the higher total antioxidant capacity values. Generally, UV-C slightly reduced initial total chlorophyll content but delayed its degradation throughout shelf-life. It is concluded that a pre-treatment of 4.5 kJ UV-C m^{-2} is useful as a technique to improve epiphytic microbial quality and health promoting bioactive compounds of fresh-cut Bimi® broccoli.

1. Introduction

Broccoli is an extremely valuable horticultural product, not only in economic terms but also for its excellent health claims. This brassica species has been described as a vegetable with high nutritional value owing to its exceptionally high levels of Zn, folic acid, antioxidants, glucosinolates, fiber, vitamin C and high antioxidant activity (Jeffery et al., 2003; Freshfel, 2006; Moreno et al., 2006). After harvest, overall quality of broccoli is greatly reduced due to several detrimental changes such as loss of green colour and sepal yellowing as a consequence of chlorophyll catabolism (Funamoto et al., 2002), tissue disruption, lipid peroxidation, protein degradation and the loss of antioxidant and health promoting bioactive compounds, which decreases nutritional value (Page et al., 2001).

New varieties of broccoli with less intense flavor than the conventional ones are appearing in the international market in order to increase their consumption. Bimi® broccoli, a new commercial broccoli variety (also called as tenderstem®, vellaverde®, broccolini®, asparation, inspiration, broccoletti or broccolette) is a hybrid between conventional broccoli (*Brassica oleracea*, Italica group) and Chinese broccoli (*B. oleracea*, Alboglabra group, also called kai-lan or Chinese kale). Bimi® looks like conventional broccoli with a long slender stem, but has a milder sweeter taste similar to green asparagus (Fig. 1).

The current worldwide drive for a healthier lifestyle has led to a rising demand for convenient fresh foods, free from additives, with high nutritional value, antioxidant and free-radical scavenging properties, to be consumed both in the retail and food service sectors. In particular, fresh-cut fruit and vegetables offer great advantages for consumers, owing to their convenience and ready-to-use properties, although they provide an ideal medium for microbial development (Artés et al., 2009). UV-C treatments (0.5–20 kJ m^{-2}) decrease microbial growth by inducing the formation of pyrimidine dimers that alter the DNA helix and block microbial cell replication (Nakajima et al., 2004). The effectiveness

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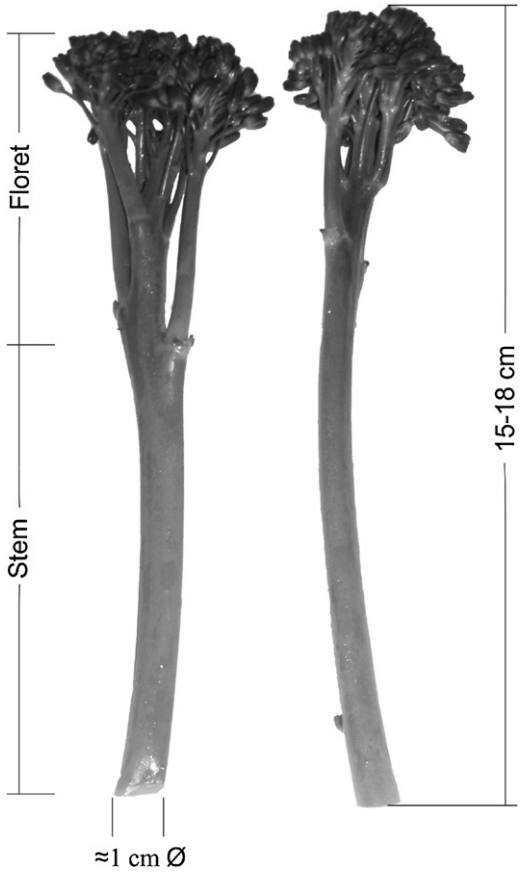

Fig. 1. Visual appearance and different morphological parts of Bimi® broccoli.

of UV-C seems to be independent of temperature in the range 5–37 °C, but it depends on the incident irradiation (Bintsis et al., 2000). It has been hypothesised that selected abiotic stress such as UV-C radiation could affect the secondary metabolism of fresh produce and could increase the synthesis of phytochemicals with nutraceutical activity (Cisneros-Zevallos, 2003).

The aim of the present work was to study the effect of four pre-packaging UV-C treatments and two storage temperatures on the main quality changes of fresh-cut Bimi® broccoli throughout shelf-life. To the best of our knowledge, no other studies on the postharvest behaviour of this broccoli hybrid have been published.

2. Materials and methods

2.1. Plant material

Bimi® broccoli (*B. oleracea* Italica Group × Alboglabra Group) was grown as a field crop in the Southeast Mediterranean coast by Campo de Lorca SCL (Murcia, Spain). Immediately after hand-harvesting, the broccoli was forced-air pre-cooled at 1 °C and then transported with top icing about 90 km to the Pilot Plant of the Technical University of Cartagena (UPCT), where it was stored in a cold room at 1 °C. The following morning the broccoli was processed.

2.2. Sample preparation, treatments and storage conditions

Plant material was minimally processed in a disinfected cold room at 8 °C. Broccoli was selected with a stem length between 15 and 18 cm, stem diameter 6–12 mm, 4 nodes per stem maximum, with no yellowing or damage and devoid of leaves. The raw material was washed for 1 min with tap water at 5 °C to remove traces of soil and organic matter. The following UV-C radiation treatments were applied: 0 (Control), 1.5, 4.5, 9.0 and 15 kJ UV-C m^{-2}. UV-C exposure times ranged between 37 and 375 s. Such doses were selected based on previous reports and our preliminary experiments. The UV-C equipment has been earlier described (Artés-Hernández et al., 2010).

For passive modified atmosphere packaging (MAP), samples of about 200 g of broccoli per treatment were randomly placed in 1.2 L polypropylene (PP) baskets and thermally sealed on the top with a 50 μm microperforated bi-oriented PP film (BOPP) (Plásticos del Segura, Murcia, Spain). The O_2 and CO_2 transmission rates at 23 °C and 0% RH were similar with 11,000 $cm^3\ m^{-2}\ d^{-1}\ atm^{-1}$ (data provided by the supplier). Three replicates of one basket per treatment and MAP storage duration (processing day and after 7, 13, 16 and 19 days) were prepared and stored in dark cold rooms at 5 or 10 °C. The 5 °C temperature was selected as the maximum recommended during shelf-life for fresh-cut broccoli and 10 °C as an abuse temperature during storage, distribution and retail sale.

2.3. Analysis and determinations

2.3.1. Respiration rate and gas analysis within modified atmosphere packages

The respiration rate (RR) of broccoli was determined using a closed system. Three replicates of 80–90 g were placed within 750 mL glass jars at 5 or 10 °C up to 19 days. The increases in CO_2 were monitored after closing the jars for 2 h. Headspace gas samples (1 mL) were withdrawn from the jars with a gas-tight syringe and analyzed in a gas chromatograph (GC PerkinElmer Precisely Clarus 500, Massachusetts, USA). The GC was equipped with a thermal conductivity detector (90 °C), oven (temperature gradient from 40 to 90 °C), injector (150 °C) and with a Porapack Qs 80/100 (Barcelona, Spain) and Molecular Sieve 5A 45/60 (Barcelona, Spain) columns. Calibration of CO_2, O_2 and N_2 was done with known standards from gas cylinders (Air Liquid SA, Murcia, Spain). Three replicates were made for each treatment and evaluation period.

Throughout shelf-life gas composition (O_2 and CO_2) within packages was monitored. Headspace gas samples (1 mL) were withdrawn and analyzed in the GC described above from three replicates for each treatment and evaluation period.

2.3.2. Microbial analysis

To determine the microbial growth standard, enumeration methods were used. Three random samples were taken at each evaluation time. Samples of 20 g were homogenized in 180 mL of sterile peptone saline solution (pH 7) (Scharlau Chemie SA, Barcelona, Spain) for 1 min in a sterile stomacher bag (Model 400 Bags 6141, London, UK) using a masticator (Colwort Stomacher 400 Lab, Seward Medical, London, UK). For the enumeration of each microbial group (mesophilic, enterobacteria, psychrotrophic, yeasts and moulds), ten-fold dilutions series were prepared in 9 mL of sterile peptone saline solution. Mesophilic, enterobacteria and psychrotrophic were pour-plated and yeast and mould were spread-plated. The following media and incubation conditions were used: plate count modified agar (Scharlau Chemie, Barcelona, Spain) for mesophilic and psychrotrophic aerobic bacteria, incubated at 30 °C for 48 h and at 5 °C for 7 days respectively; violet red bile dextrose agar (Scharlau Chemie, Barcelona, Spain) for enterobacteria, incubated at 37 °C for 48 h and potato dextrose agar base (Scharlau Chemie, Barcelona, Spain) with oxytetracycline (100 mg L^{-1}) (Sigma Chemical Co., St Louis, MO, USA) for yeasts and moulds, incubated for 3–5 days at 22 °C. All microbial counts were reported as log colony forming units per gram of product (log CFU g^{-1}).