



# Effect of light exposure on sensorial quality, concentrations of bioactive compounds and antioxidant capacity of radish microgreens during low temperature storage



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## ABSTRACT

Radish microgreens constitute a good source of bioactive compounds; however, they are very delicate and have a short shelf life. In this study, we investigated the impact of light exposure and modified atmosphere packaging on sensorial quality, bioactive compound concentrations and antioxidant capacity of radish microgreens during storage. Results showed that light exposure during storage increased the amount of ascorbic acid and had no effect on  $\alpha$ -tocopherol or total phenolic concentrations. Dark storage resulted in higher hydroxyl radical scavenging capacity and carotenoid retention. No significant differences were found for relative 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging capacity between light and dark treatments. Radish microgreens in bags of  $29.5 \text{ pmol s}^{-1} \text{ m}^{-2} \text{ Pa}^{-1}$  oxygen transmission rate (OTR) maintained better quality than those within laser microperforated bags. In conclusion, light exposure accelerated deterioration of radish microgreens, while dark storage maintained quality; and application of OTR bags was beneficial in extending shelf life.

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## 1. Introduction

Microgreens are a new class of specialty vegetables that are often harvested at the cotyledonary leaf stage without roots and seed coats. Microgreens are favored by chefs and consumers in high-end restaurants for their attractive colours, tender textures, and intense flavors. A recent report on phytonutrient studies (Xiao, Lester, Luo, & Wang, 2012) demonstrated that most microgreens contain substantially higher levels of bioactive compounds, such as ascorbic acid, phylloquinone, tocopherols and carotenoids, than their more mature true-leaf forms. As the demand for microgreens increases, and they begin to appear in farmer's markets and specialty grocery stores, the optimization of their postharvest storage conditions is therefore becoming important.

Commercially, containers used for microgreens are plastic clamshell containers, in which the gas composition is atmospheric. In order to accurately measure the headspace gas composition, laser microperforated plastic bags were used in the current study as substitutes for clamshell containers. However, our previous studies found that using optimized modified atmosphere packaging

considerably extended the shelf-life of radish microgreens (Xiao et al., 2013). Thus both packaging conditions will be investigated.

Fresh produce, including microgreens, are usually displayed under light in grocery stores. Recently, the effect of light exposure on quality and phytochemical concentrations of different vegetables has been studied extensively. Büchert, Lobato, Villarreal, Civello, and Martinez (2011) reported that continuous low intensity light delayed yellowing and postharvest senescence of broccoli florets (*Brassica oleracea* L.). Noichinda, Bodhipadma, Mahamontri, Narongruk, and Ketsa (2007) reported that low intensity fluorescent light accelerated fresh weight loss, but prevented the loss of vitamin C of Chinese kale (*B. oleracea* var. *alboglabra*) during storage. Lester, Makus, and Hodges (2010) found that continuous light exposure prevented loss of ascorbic acid and was beneficial in enhancing the amounts of carotenoids and tocopherols of baby-leaf spinach (*Spinacia oleracea* L.). Studies also showed that light exposure could cause detrimental effects on produce quality. For example, a study by Sanz, Olarte, Ayala, and Echavarrri (2009) demonstrated that asparagus (*Asparagus officinalis* L.) stored under light experienced accelerated deterioration and shortened shelf life than those stored under continuous dark. Martinez-Sanchez, Tudela, Luna, Allende, and Gil (2011) also observed that light exposure could promote browning of fresh-cut Romaine lettuce (Martinez-Sanchez et al., 2011).

Daikon radish microgreens (*Raphanus sativus* var. *longipinnatus*) were chosen in this study due to its abundance in bioactive com-

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pounds relevant to human health (Xiao et al., 2012) and broad usage in restaurants in the US. The objective of this study is to determine the effect of light exposure and packaging conditions on sensorial quality, concentrations of bioactive compounds, and antioxidant capacity of daikon radish microgreens during cold storage.

## 2. Materials and methods

### 2.1. Sample preparation

Daikon radish microgreens (*R. sativus* var. *longipinnatus*) were grown by Sun Grown Organic Distributors, Inc. (San Diego, CA) in an unheated greenhouse and under ambient light. Samples were harvested without roots, packaged in clamshell containers and shipped overnight in insulated containers with ice packs. All samples were inspected prior to packaging and defective plant tissues were discarded. Samples (20 g) were re-packaged in 12.5 cm × 12.5 cm plastic bags, which were made of either polyethylene film (Pacific Southwest Container Inc., Modesto, CA) with OTR of 29.5 pmol s<sup>-1</sup> m<sup>-2</sup> Pa<sup>-1</sup> or laser microperforated oriented polypropylene film (LMP), provided by Dole Fresh Vegetables, Inc. (Salinas, CA), respectively. The samples in each packaging type were further randomly divided into two groups and subjected to light and dark treatments. The samples subjected to light were stored under continuous fluorescent light (light intensity ≈ 30 μmol s<sup>-1</sup> m<sup>-2</sup>) and those receiving dark treatment were stored in two-layer brown paper bags (light intensity ≈ 0.1 μmol s<sup>-1</sup> m<sup>-2</sup>). The light intensity was measured by LI-1000 dataloggers (LI-COR, Lincoln, NB) at the top of packages. Three packages of radish microgreens were randomly selected from each treatment on day 0, 4, 8, 12 and 16 for evaluations.

### 2.2. Headspace gas composition

Packaging headspace gas samples were withdrawn by inserting the needle through a septum adhered to the packaging film. The gas composition (O<sub>2</sub> and CO<sub>2</sub>) was measured using an O<sub>2</sub>/CO<sub>2</sub> gas analyzer (CheckMate II, PBI-Dansensor A/S, Ringsted, Denmark).

### 2.3. Quality attributes

#### 2.3.1. Colour (*L*<sup>\*</sup>, *C*<sup>\*</sup>, *h*<sup>°</sup>)

Colour coordinates (CIE *L*<sup>\*</sup>, *C*<sup>\*</sup>, *h*<sup>°</sup>) were directly measured on the products using a model CR-410 colorimeter (Konica Minolta, Ramsey, NJ) with a 50 mm diameter viewing aperture. The equipment was calibrated with a standard white plate (*Y* = 94.0, *x* = 0.3130 and *y* = 0.3191). The concentrations of each package of radish microgreens were transferred to a clear plastic tray. Colour was measured at ten locations and the mean value was taken to ensure that colour readings were representative of each sample. Three replicate packages were evaluated for each treatment on each sampling day (day 0, 4, 8, 12 and 16). The results were expressed as lightness (*L*<sup>\*</sup>), Chroma (*C*<sup>\*</sup>) and hue angle (*h*<sup>°</sup>) values.

#### 2.3.2. Weight loss

Weight loss was determined by weighing the bagged samples at the beginning of storage and during storage. Three replicates were evaluated for each treatment on each sampling day (day 0, 4, 8, 12 and 16). Results were expressed as percentage of weight loss relative to the initial fresh weight.

#### 2.3.3. Sensory evaluation

Sensory evaluation was conducted by a six-member trained panel using a ballot designed with Compusense<sup>®</sup> 5.0 system (Guleph, Canada). All the samples were evaluated under controlled yellow light in individually partitioned sensory booths. A total of 4

samples, one from each of the four treatments were served one at a time to each panelist. Each sample was labeled with a random 3-digit number and served to the panel members in random orders. The visual quality was rated using a 9-point hedonic scale, anchored by 9 = like extremely, 5 = neither like nor dislike and 1 = dislike extremely, (Meilgaard, Civille, & Carr, 1991); a score of 6 was considered the limit of salability (Kim, Luo, & Gross, 2004). Off-odour was scored on a 0–4 scale where 0 = no off-odour, 1 = slight off-odour, 2 = moderate off-odour, 3 = strong off-odour, and 4 = extremely strong off-odour.

### 2.4. Analysis of bioactive compounds

#### 2.4.1. Ascorbic acid

Total ascorbic acid (TAA) and free ascorbic acid (AA) were determined using a reverse phase high performance liquid chromatography (RP-HPLC) according to the method published by Bartoli et al. (2006) with modifications. In this assay, dehydroascorbic acid (DAA), the oxidized form of AA, was reduced to AA for TAA determination. Fresh tissue (3 g) was ground in 10 mL of ice-cold 5% (w/v) meta-phosphoric acid at the speed of 15,000 rpm for 1 min in ice-water bath using a polytron homogenizer (Brinkman Instruments, Westbury, NY). The mixture was centrifuged at 7000g (Beckman J2-MI, Beckman Coulter, Inc., Irving, TX) for 15 min at 4 °C, and the supernatant was filtered through Whatman #4 filter paper (Millipore Corp. Bedford, MA). Ascorbic acid was detected with a photodiode array detector (DAD) (G1315C) on an Agilent 1200 series HPLC system (Agilent, Santa Clara, CA) at 243 nm. The extract was filtered through a 0.22 μm nylon syringe filter (Millipore, Bedford, MA) and then directly injected (vol. = 10 μL) into the HPLC system and run through a C18 column (Luna, 5 μm, 250 × 2.0 mm, Phenomenex, Torrance, CA) with an isocratic mobile phase (100 mM phosphate buffer, pH = 3.0) flowing at the rate of 0.6 mL/min. Total AA was determined by HPLC after reducing DAA by mixing the same volume of the sample filtrate with 5 mM dithiothreitol (DTT) in 150 mM phosphate buffer (pH = 7.4 with 5 mM EDTA) for 15 min in darkness. Concentrations of TAA and AA were quantified based on peak areas using a reduced ascorbic acid standard curve (*R*<sup>2</sup> ≥ 0.99), and their difference was equal to the concentration of DAA.

#### 2.4.2. Carotenoids and tocopherols

Carotenoids and tocopherols were simultaneously determined using an isocratic RP-HPLC according to the procedure previously established in our laboratory (Xiao et al., 2012). Briefly, 500 μL of internal standard (86.82 μM trans-β-apo-8 carotenal) and 7.5 mL of 1% butylated hydroxytoluene (BHT) in ethanol were added into 15 mL screw cap glass vial containing 0.05 g of lyophilized samples and homogenized for 15 s using a sonic dismembrator (Model 300, Fisher Scientific Inc., Pittsburg, PA). The vials were capped under a stream of N<sub>2</sub> and placed in a 70 °C dry bath. After 15 min, 180 μL of 80% KOH was added and incubated for another 30 min, after which, vials were cooled down for 5 min in ice, and then transferred into 15 mL centrifuge tubes. After adding 3.0 mL of deionized water and 3.0 mL of hexane/toluene solution (10:8 v/v), the mixture was vortexed for 1 min, and then centrifuged at 1000g (Clay Adams Dynac II Centrifuge, Block Scientific, Inc., Bohemia, NY) for 5 min. The top organic layer was collected into an 8 mL glass culture tube, and immediately placed into a nitrogen evaporator (Organomation Associates, Inc., Berlin, MA) set at 30 °C and flushed with stream of N<sub>2</sub>. The bottom layer was extracted again with 3.0 mL of hexane/toluene solution (10:8 v/v) for further partition. This extraction was repeated at least four times until the top layer was colourless, and all the supernatants were combined. After drying, the residue was reconstituted in 500 μL of mobile phase acetonitrile/ethanol (1:1 v/v). The mixture was filtered via a

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