LWT - Food Science and Technology 60 (2015) 109–114

Contents lists available at ScienceDirect

LWT - Food Science and Technology

journal homepage: www.elsevier.com/locate/lwt

Quality retention of fresh-cut pepper as affected by atmosphere gas composition and ripening stage

Luis Rodoni [a], Ariel Vicente [a, b, *], Sílvia Azevedo [c], Analía Concellón [a, d], Luís M. Cunha [c]

[a] Centro de Investigación y Desarrollo en Criotecnología de Alimentos (CIDCA) CONICET-UNLP. Calle 47 esq. 116, La Plata CP 1900, Argentina
[b] LIPA: Laboratorio de Investigación en Productos Agroindustriales, Facultad de Ciencias Agrarias y Forestales, Universidad Nacional de La Plata, Calle 60 y 119, La Plata CP 1900, Argentina
[c] REQUIMTE/DGAOT, Faculdade de Ciências da Universidade do Porto, Rua do Campo Alegre s/n, 4169-007 Porto, Portugal
[d] CIC, Comisión de Investigaciones científicas, Pcia. Bs. As., Argentina

ARTICLE INFO

Article history:
Received 28 April 2014
Received in revised form
19 August 2014
Accepted 20 August 2014
Available online 6 September 2014

Keywords:
Capsicum annuum L.
Microbial growth
Texture
Color
Storage

ABSTRACT

The responses of fresh-cut (FC) vegetables to CO_2 and O_2 levels depend on their ripening stage and degree of processing. In this work we evaluated the effect of storage under different CO_2 (2.5; 5; 10 and 15 kPa) and O_2 (2.5 and 5 kPa) combinations or air on quality retention of FC green and red pepper. Atmospheres with 15 kPa CO_2 caused physiological injury at both ripening stages. Red pepper strips were less tolerant to CO_2 enrichment within the range 5–10 kPa. Ripe FC peppers were also more sensitive to O_2 reductions below 5 kPa. Marked benefits were obtained at both ripening stages with 5 kPa O_2 + 5 kPa CO_2. CA-stored strips showed lower spoilage and dehydration and ion leakage. Storage under 5 kPa O_2 + 5 kPa CO_2 was highly effective to maintain the firmness and resistance to bending of the strips. The selected CA caused no alterations in color, acidity, sugars and antioxidants and was effective to maintain lower respiration rate. CA maintained lower counts of mesophilic bacteria, yeasts and molds in red ripe strips.

1. Introduction

Sweet peppers are together with tomato the most popular *Solanaceous* fruit marketed worldwide (Howard, Talcott, Hernandez-Brenes, & Villalon, 2000; Marín, Ferreres, Tomás-Barberán, & Gil, 2004). They are consumed at green and red ripe stages either cooked in sauces and prepared foods or minimally processed in salads and snacks (Tadesse, Hewett, Nichols, & Fisher, 2002). Fresh-cut (FC) products are one of the fastest growing segments of the vegetable industry (Clement, 2004). By saving preparation time and reducing wastage, minimal processing improves commodity use convenience (Oms-Oliu et al., 2010). However, processing causes a number of physical and physiological changes which increase perishability (Corbo, Speranza, Campaniello, D'Amato, & Sinigaglia, 2010; Watada, Ko, & Minott, 1996). FC products consequently require a tightly adjusted postharvest management. Proper temperature management is a *sine qua non* condition, but even under recommended storage temperatures, deteriorative changes are extremely rapid (Rojas-Graü, Oms-Oliu, Soliva-Fortuny, & Martín-Belloso, 2009; Weichmann, 1986). Modified atmosphere packaging has been recommended for some FC products (Gorny, 2001). Optimal storage atmosphere conditions depend on the type of commodity as well as on its developmental stage and processing degree (Oms-Oliu, Aguiló-Aguayo, Soliva-Fortuny, & Martín-Belloso, 2009). Modified atmosphere packing (MAP) did not result in marked improvement in quality retention of whole peppers (Akbudak, 2008; Koide & Shi, 2007; Saltveit, 1997). However, the results reported in the literature are quite variable. Hypo-oxygenic atmospheres ranged from lack of any benefit (Mercado, Valpuesta, Reid, & Cantwell, 1995) to high decay control (Luo & Mikitzel, 1996). Previous studies evaluating the efficacy of MAP and the effects of CO_2 on FC pepper also showed wide variability. González-Aguilar, Ayala-Zavala, Ruiz-Cruz, Acedo-Félix, and Díaz-Cinco (2004) reported that atmospheres reaching 10 kPa CO_2 and 2 kPa O_2 maintained quality for 21 days, whereas in other studies marked deterioration was observed already after 12 days (López-Gálvez, El-Bassuoni, Nie, & Cantwell, 1997). El-Bassuoni and Cantwell (1994) found increased softening and electrolyte leakage in green FC pepper stored under 10 kPa

* Corresponding author. LIPA: Laboratorio de Investigación en Productos Agroindustriales, Facultad de Ciencias Agrarias y Forestales, Universidad Nacional de La Plata Calle 60 y 119. La Plata CP 1900, Argentina. Tel.: +54 2214236758x441.
E-mail addresses: arielvicente@quimica.unlp.edu.ar, arielvicente@gmail.com (A. Vicente).

http://dx.doi.org/10.1016/j.lwt.2014.08.023
0023-6438/

CO_2. In contrast no damage was observed under similar atmospheres by González-Aguilar et al. (2004). Most works conducted to date on MAP of FC peppers have tested one ripening stage and a single gas combination (Howard & Hernandez-Brenes, 1997; Pilon, Oetterer, Gallo, & Stopo, 2006). Moreover, the effects of O_2 on quality maintenance of FC pepper have also received little attention. In this work we evaluated the influence of atmosphere gas composition and ripening stage on quality retention of fresh-cut red and green pepper.

2. Materials and methods

2.1. Plant material

Bell peppers (*Capsicum annuum* L.) at green and red stages were purchased at the Mercado Abastecedor do Porto, Porto, Portugal and immediately transported to the laboratory. Fruit was washed with water containing 100 mg L^{-1} sodium hypochlorite and adjusted to pH 6.5 with hydrochloric acid, for 3 min. The fruit peduncles, placenta and seeds were removed, and the pericarp was cut into 5 × 1 cm strips and rapidly cooled to 5 ± 0.5 °C.

2.2. Experimental setup and selection of optimal atmosphere composition for green and red pepper strips

A gas mixer (MAP Mix 9000, PBI Dansensor, Denmark), coupled to an external buffer tank was used to adjust the desired concentration of O_2, CO_2 and N_2. The following gas combinations were prepared with N_2 used as a balance gas:

i. Air (control)
ii. 2.5 kPa CO_2; 2.5 kPa O_2
iii. 5 kPa CO_2; 2.5 kPa O_2
iv. 10 kPa CO_2; 2.5 kPa O_2
v. 15 kPa CO_2; 2.5 kPa O_2
vi. 2.5 kPa CO_2; 5 kPa O_2
vii. 5 kPa CO_2; 5 kPa O_2
viii. 10 kPa CO_2; 5 kPa O_2
ix. 15 kPa CO_2; 5 kPa O_2

Prior to flushing each gas mixture was bubbled through water, to increase the relative humidity (RH). The RH inside the jars was recorded with a (Rotronic HygroPalm HP21, Switzerland) and was in all cases between 85 and 93%. One hundred and 50 g of green or red bell pepper strips were placed in 1.9 L glass sealed jars containing two ball valves. Three replicates were prepared for each ripening stage, and gas mixture. The jars were connected to a gas circulation system (5 mL min^{-1}) and the fruit was stored for 7 and 10 days at 5 °C in darkness with the gas mixtures indicated above. The headspace from each jar was daily monitored with an O_2/CO_2 gas analyzer (Check Mate 9900, PBI Dansensor, Denmark). After 0, 7 and 10 days samples were taken and fruit quality was visually evaluated on individual pepper strips, based on the incidence of soft rots and molds, dehydration and softening symptoms by using an intensity scale (0 = excellent; 1 = good; 2 = acceptable; 3 = poor). Strips decayed or having extensive softening were classified as poor. Samples with moderate softening or dehydration but without decay, were categorized as acceptable. Strips showing no marked softening and slight dehydration in the cut surfaces were considered good. Excellent strips showed no visual symptoms of decay or dehydration and remained firm. The deterioration index (DI) was calculated as follows: DI = ∑(Injury level × Number of fruit strips in this level)/Total number of strips.

2.3. Effect of the selected atmosphere on green and red pepper strips quality

Fresh-cut green and red peppers were prepared as described in section 2.1 and stored in a) air (control) or b) under 5 kPa O_2 + 5 kPa CO_2 at 5 °C for 0, 7 or 12 days. Five jars containing 30 pepper strips were prepared for each treatment, ripening stage and storage time. The whole experiment was repeated twice. Samples were taken prior to storage after 7 and 12 days and immediately evaluated or otherwise frozen in liquid N_2 and stored at −80 °C until analysis.

2.3.1. Respiration rate

Pepper strips weighing approximately 150 g were placed in hermetically sealed jars. Samples from the headspace were withdrawn through a silicon septum located on each jar with a syringe, at the beginning of the incubation period and after 1 h to allow CO_2 accumulation. Gas samples were evaluated with a gas analyzer (Check Mate 9900 O_2/CO_2; PBI Dansensor; Denmark). Four jars were analyzed for each storage time, ripening stage and gas treatment. Results were expressed as mg CO_2 kg^{-1} h^{-1}.

2.3.2. Mass loss and soft rots

Five groups of 30 pepper strips were weighed at the beginning of the experiment, and during storage. Mass loss was calculated as 100 × (W_i − W_f)/W_i, where W_i and W_f represented the initial and final sample mass, respectively. Soft rots were visually evaluated on individual strips by using an intensity scale (0 = no soft rots; 1 = incipient soft rots; 2 = moderate soft rots; 3 = severe soft rots). A soft rot index was calculated as: SRI = ∑(Injury level × Number of fruit strips in this level)/Total number of strips.

2.3.3. Color

Surface color was measured on the outer side of the strips with a chroma meter (Model CR-400, Minolta, Osaka, Japan) to obtain CIE L^*; a^*; b^* values. The hue angle was calculated as 180 − tg^{-1} b^*/a^* and tg^{-1} b^*/a^* for green and red peppers respectively. Sixty measurements were done for each gas treatment, ripening stage, and storage time.

2.3.4. Texture

Texture was evaluated by two different assays using an INSTRON texture analyser (Model 2519-101, INSTRON, USA) with a 10 N load cell. For bending tests, bell pepper strips (5 cm × 1 cm and 4 mm thick) were horizontally held (1 cm from each end). A probe with circular flat tip (6 mm diameter) was used to displace the middle of the strips at a speed of 7.5 mm s^{-1} and the force required for bending (15 mm) was determined. The resistance to deformation was calculated as the slope of the force/time curves. Results were expressed in N s^{-1}. Puncture tests were performed on the inner side of the pepper strips by compressing the fruit tissue 2 mm in the middle of the strip, at a rate of 2 mm s^{-1} with a 1 mm diameter probe and recording the maximum force developed during the test. Results were expressed in Newton (N). For both assays thirty pepper strips were randomly selected from each jar and evaluated for each gas treatment, ripening stage and storage time.

2.3.5. Sugars, pH and acidity

Frozen pulp tissue was processed in a refrigerated mill and 2 g of the resulting powder were extracted with 10 mL of ethanol. The mixture was centrifuged (MPW-350R, Poland) at 9000 × g for 10 min at 4 °C. Three independent extractions were done for each storage time. Total sugars content was measured using the phenol–sulfuric acid assay (Southgate, 1976) with D-glucose as a standard at 490 nm in a spectrophotometer (Spectronic GENESYS 6,