Food Sci. and Technol. Int. 23: 3-16

Effect of antibrowning dips and controlled atmosphere storage on the physico-chemical, visual and nutritional quality of minimally processed 'Rojo Brillante' persimmons

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Abstract

The combined effect of antibrowning dips and controlled atmosphere storage on fresh-cut 'Rojo Brillante' persimmon quality was investigated. Persimmon slices were dipped in 10 g L^{-1} ascorbic acid (AA), 10 g L^{-1} citric acid (CA) or water, and were stored in different controlled atmospheres at 5 ºC. Controlled atmosphere conditions were 21 kPa O_2 + 10 kPa CO_2 (Atm-B), 21 kPa O_2 + 20 kPa CO_2 (Atm-C), 5 kPa O_2 + 10 kPa CO_2 (Atm-D), and 5 kPa O_2 in the absence of CO_2 (Atm-E). Air (Atm-A) was used as a control. Atmospheres with high CO_2 concentrations induced darkening, associated with a flesh disorder known as 'internal flesh browning'. Only the samples placed in Atm-E, and treated with 10 g L^{-1} AA or 10 g L^{-1} CA, controlled enzymatic browning, reduced firmness loss and prevented the 'internal flesh browning' disorder. The maximum limit of marketability was achieved in the samples treated with 10 g L^{-1} CA and stored in Atm-E for 9 storage days at 5 ºC. The total vitamin C, free radical scavenging activity, total phenolic content, and total carotenoids of the fresh-cut 'Rojo Brillante' persimmons were affected by maturity stage at harvest, whereas antibrowning dips and controlled atmosphere storage had no clear effect.

Keywords

Fresh-cut, firmness, ascorbic acid, citric acid, browning, bioactive compounds.

INTRODUCTION

Persimmon (*Diospyros kaki* Thunb.) production is widely extended worldwide and has presented an upward trend in the last decade, mainly in the Mediterranean region with the expansion of cultivar 'Rojo Brillante' (Valencia, Spain). This cultivar is very much appreciated in European markets for its size, color and flavor, and because it is a good source of bioactive compounds (Plaza et al., 2012). This fruit is astringent at harvest, but the application of high CO_2 concentrations allows astringency to be removed, while fruit firmness is preserved. This technology also enables the commercialization of 'Rojo Brillante' persimmon fruit as a fresh-cut commodity. However, minimally processing leads to enzymatic browning and softening, which significantly reduces the product's shelf life (Sanchís et al., 2015). Several physical and chemical treatments, such as antibrowning dips and modified atmosphere storage, may be applied in synergy with proper temperature management to extend the shelf life of fresh-cut fruits. In recent works, dips in antibrowning solutions of 10 g L^{-1} ascorbic acid (AA) or 10 g L^{-1} citric acid (CA) have controlled the tissue browning of fresh-cut 'Rojo Brillante' persimmons and maintained visual quality above the limit of marketability by up to 6-8 storage days at 5 ºC. The limit of marketability was strongly affected by the fruit's maturity stage at harvest (Ghidelli et al., 2013; Sanchís et al., 2015).

The successful application of modified atmosphere packaging with low O_2 and high CO_2 for fresh-cut fruits and vegetables has been extensively reported in the literature, and optimal atmospheres have been recommended for some fresh-cut fruits and vegetables (Gorny, 2003). However, caution must be taken in applying the recommended atmospheres since a product may respond in various ways as a result of differences in physiological maturity, growing conditions, postharvest handling conditions prior to cutting, and the expected storage/distribution temperature. Therefore,

68 studying the efficacy of a given recommendation for a specific situation before applying
69 it in commercial practice is recommended (Toivonen et al., 2009).

70 The study of controlled atmospheres is generally the first step to select optimum
71 O_2 and CO_2 concentrations for modified atmosphere packaging. Wright and Kader
72 (1997a) reported that 'Fuyu' persimmons slices stored under controlled atmosphere
73 conditions (2 kPa O_2 + 12 kPa CO_2) maintained good visual quality for up to 8 storage
74 days at 5 ºC, whereas areas of faint black pigmentation had begun to develop on the
75 fruit stored in air. This cultivar also showed loss in vitamin C and carotenoid content
76 during controlled atmosphere storage after being cut (Wright and Kader, 1997a, 1997b).
77 Therefore, the aim of this study was to evaluate the effect of ascorbic or citric acid dips
78 in combination with different controlled atmospheres on the physico-chemical, visual
79 and nutritional quality of fresh-cut 'Rojo Brillante' persimmons harvested in two
80 commercial maturity stages.

81

82 **MATERIALS AND METHODS**

83 This study was conducted during two growing seasons and included two experiments.
84 In the first experiment, the study was done to identify successful combinations of
85 antibrowning agents and different controlled atmosphere conditions. In the second
86 experiment, selected controlled atmosphere conditions were tested in the persimmon
87 fruits harvested in two different commercial maturity stages (MSs).

88

89 **Reagents and solvents**

90 Ascorbic acid (AA) and citric acid (CA) were supplied by Quimivita (Barcelona,
91 Spain). 2,2-diphenyl-1-picrylhydrazyl (DPPH), Folin–Ciocalteu reagent, sodium
92 carbonate, sodium chloride, ammonium acetate, β-apo-8'-carotenal and β-carotene were

obtained from Sigma (St. Louis, MO, USA). Methanol, chlorhydric acid, ethanol, hexane, methylene chloride, acetonitrile and butylated hydroxytoluene were purchased from Scharlau (Barcelona, Spain). β-cryptoxanthin, lutein, lycopene and zeaxanthin were supplied by Extrasynthese (Genay, France). Gallic acid came from Acros Organics (Geel-Belgium) and thriethylamine from Panreac (Barcelona, Spain). All the solvents were of HPLC-grade and Milli-Q system ultra-pure water (Millipore Corp., USA) was used throughout this research work.

Plant material and sample preparation

Persimmon fruits (*Diospyros kaki* cv. Rojo Brillante) were provided by the Protected Designation of Origin (PDO) Kaki Rivera del Xúquer (Valencia, Spain). These fruits were harvested during two persimmon seasons at commercial MS determined by external color as a color index (CI=1,000 a/L b using the Hunter L, a, b color space) (Salvador et al., 2007). For experiment 1, fruits were harvested in mid-November and had a CI of 8.4 ± 0.3 and flesh firmness of 40.0 ± 0.5 N. For experiment 2, persimmons were harvested in early October (MS1) and mid-November (MS2), which corresponded to the beginning and end of the season, respectively. The CI and flesh firmness were -0.6 ± 0.2 and 65.6 ± 0.4 N for MS1 and 14.1 ± 0.7 and 41.5 ± 2.5 N for MS2, respectively.

Before processing, astringency was removed according to commercial practices by applying 95% of CO_2 in closed containers for 24 h at 20 ºC and at 90% relative humidity (RH) (Arnal and del Rio, 2003). The persimmons pre-cooled at 5±1ºC for 20 h were washed with chlorinated water (150 mg L^{-1}), peeled and cut into eight wedges. Pieces were dipped for 3 min in 10 g L^{-1} AA, 10 g L^{-1} CA or water as a control, and

were allowed to drain and dry at 5±1ºC before storage under controlled atmosphere conditions.

Controlled atmosphere storage treatments

In experiment 1, the controlled atmosphere treatments of 21 kPa O_2 + 10 kPa CO_2 (Atm-B), 21 kPa O_2 + 20 kPa CO_2 (Atm-C), and 5 kPa O_2 + 10 kPa CO_2 (Atm-D) were compared to air (Atm-A). In experiment 2, the controlled atmosphere treatments of 5 kPa O_2 + 10 kPa CO_2 (Atm-D) and 5 kPa O_2 (Atm-E) were compared to air (Atm-A). All the gas mixtures were balanced with N_2. Fruit slices were placed in 2-L glass jars at 5 ºC under a continuous air flow or the specified gas mixture humidified by passing through distilled water to maintain 90-95% RH. The flow rate was 35 mL/min to prevent ethylene accumulation. The gas composition, as supplied to the jars, was measured with a gas analyzer (PBI Dansensor, Check Mate 9900, Ringsted, Denmark). Persimmon slices were evaluated for up to 7 and 9 days for experiment 1 and 2, respectively.

Quality evaluation

The physical characteristics of the persimmon fruits before processing were evaluated in 30 fruits for external color (Minolta CR-400 chroma meter, Konica Minolta Sensing, Inc., Osaka, Japan) and firmness (Instron Universal Machine, Model 3343, Instron Corp., Canton, MA, USA). External color was expressed as the CI using the Hunter L, a, b color space and fruit firmness as the maximum force in newtons (N) required to penetrate 2 mm fruit flesh after removing skin in the equator using a 8-mm diameter probe.

In fresh-cut persimmons, color and firmness were determined on 12 pieces per treatment and sampling day. The CIE *L*a*b** color space was used to evaluate flesh color. Each measurement was taken randomly at three locations per sample piece. Fresh-cut persimmon firmness was evaluated as the force (N) required for an 8-mm diameter probe to penetrate the sample to a depth of 2 mm at a speed of 5 mm/s.

The visual quality of persimmon slices was conducted by 15 trained judges. Each treatment was presented on trays that contained 12 persimmon pieces to account for sample variability, labeled with a 3-digit random code and presented to the judges under the same conditions (light intensity and temperature) to minimize variations in human perception. Visual quality, based on general visual appearance, was determined on the following visual scale: 9 = excellent, just sliced; 7 = very good; 5 = good, limit of marketability; 3 = fair, limit of usability; and 1 = poor, inedible (Gorny et al., 2002). A color photograph of the samples rated with this scale was used to score samples.

Bioactive compounds

Total vitamin C (TVC), free radical scavenging activity, total phenolic content (TPC), and carotenoids were evaluated in fresh-cut 'Rojo Brillante' persimmons processed in two different MSs and stored 2, 5 and 9 days at 5 ºC under the different atmosphere conditions tested in experiment 2. Each sampling day, 18 persimmon slices per treatment were frozen in liquid nitrogen and kept at -80ºC until analyzed. Bioactive compounds were determined in 3 replicates per treatment.

Total vitamin C (TVC) was determined as the sum of ascorbic acid and L-dehydroascorbic acid as described by Wright and Kader (1997a). Two grams of persimmon samples, which had been stored at –80 ºC, were homogenized with 38 mL of a solution of 0.1 M citric acid and 0.05% ethylenediaminetetraacetic acid in 5%

aqueous methanol for 2 min at 22000 rpm (Ultraturrax, IKA, Germany). Two mg of D-isoascorbic acid were added as an internal standard. The homogenate was centrifuged at 12875 g for 5 min at 4 ºC. Next 1.5 mL of supernatant was reacted with 0.5 mL of 1,2-phenylenediamine (3.33 mg/mL) and diluted in methanol:water (5:95, v/v). The mix was kept for 37 min in the dark at room temperature. Afterward samples were passed though a 0.45 µm membrane filter into an amber vial and sealed to be analyzed by high pressure liquid chromatography (HPLC). The HPLC system (Lachrom Elite, Merck Hitachi, Darmstadt, Germany) was equipped with an autosampler (Model L-2200), quaternary pump (Model L-2130), a column oven (Model L-2300), and a diode array detector (Model L-2450). A reversed-phase C18 LiChroCart® column (250 x 4 mm, 5 µm particle, Merck, Darmstadt, Germany), preceded by a precolumn (4 x 4 mm), was used. The injection volume was 40 µL and the oven temperature was 4 ºC. The mobile phase was a methanol:water solution (5:95, v/v) that contained 5 mM of hexadecyltrimethylammonium bromide and 50 mM of ammonium dihydrogen phosphate, adjusted to pH 4.6. The flow rate was fixed at 1 mL/min. Ascorbic acid and D-isoascorbic acid were detected at 261 nm, whereas L-dehydroascorbic acid was detected at 348 nm. TVC was expressed as mg of TVC per 100 g sample.

The free radical scavenging activity of persimmon slices was determined by the method of Brand-Williams et al. (1995) using $DPPH^{\bullet}$ as the free radical. Extraction was done as described by Chen et al. (2008), with some modifications. Two grams of persimmon pulp were mixed with 30 mL of 80% methanol. The solution was homogenized at 20000 rpm for 2 min, followed by boiling in a water bath for 20 min to inactivate the oxidative enzymes. The homogenate was immersed in an ultrasonic machine at room temperature for 15 min and centrifuged at 12857 g for 20 min at 5 ºC. The resultant supernatant was then filtered and used as the persimmon extract. A second

pulp extraction was required to complete extraction. The mix of both extracts was used to analyze the antiradical capacity of the samples. Five methanolic dilutions from the supernatant were prepared to relate the decrease in $DPPH^{\bullet}$ absorbance with sample concentration. Seventy five µL of extract were mixed with 225 µL of $DPPH^{\bullet}$ (24 ppm) and the mixture was kept in the dark at room temperature for 20 min. The absorbance of the resulting solution was measured at 520 nm using a multiplate spectrum (Multiskan Spectrum, Thermo Fisher Scientific, Finland). $DPPH^{\bullet}$ radical scavenging activity was expressed as an effective concentration (EC_{50}). This value expresses the amount of persimmon extract required to lower the initial $DPPH^{\bullet}$ concentration by 50%; thus lower EC_{50} values mean greater antiradical capacity. Radical scavenging activity was expressed as g of persimmon fruit per kg of $DPPH^{\bullet}$.

The total phenolic content (TPC) was measured following the method described by Chen et al. (2008). One gram of frozen sample was mixed with 15 mL of methanol with 1% hydrochloric acid. This mix was homogenized at 10000 rpm for 1 min, immersed in an ultrasonic bath for 30 min and centrifuged at 12857 g for 20 min at 4ºC. The supernatant was filtered and collected. Extraction was repeated and the supernatants were combined for the analysis. Two methanolic dilutions were prepared with the extracts. Then 300 µL of supernatant were mixed with 600 µL of Folin Ciocalteu reagent and 2.4 mL of sodium carbonate solution (200 mg/mL), and in this order. The mixture was incubated for 1 h in the dark at room temperature. The absorbance of the resulting solution was measured at 765 nm with a spectrum multiplate reader. The results were expressed as mg of gallic acid per 100 g of persimmon fruit.

Carotenoids were determined as described by Wright and Kader (1997b). For the extraction, 5 g of sample were added to a centrifuge tube together with 10 mL of cold ethanol to be homogenized for 3 min at 16000 rpm. Eight mL of hexane were added and

the sample was homogenized for another 2 min. The mixture was then centrifuged for 4 min at 3214.25 g and 4 ºC. The organic phase was transferred to a 250-mL screw-cap Erlenmeyer flask. The extraction was repeated with 5 mL of saturated sodium chloride and 8 mL of hexane. The resultant organic phase was transferred to the Erlenmeyer flask with the first extract. For saponification, 15 mL of 10% methanolic potassium hydroxide were added to the Erlenmeyer flask. The flask was flushed with nitrogen, sealed, covered with aluminum foil to prevent oxygen and light, and left at room temperature for 16 h with gentle shaking. Next the mixture was transferred to a separatory funnel to remove the potassium hydroxide with 15 mL of 10% sodium chloride, followed by deionized water until the pH of the mixture became neutral. The final extract was evaporated under nitrogen until dryness and was kept at -80 ºC until analyzed. At the time of the analysis, samples were redissolved in 200 µL of methylene chloride and 1.8 mL of the mobile phase. The major carotenoids were determined by HPLC. For the analysis, the resuspended sample was filtered into amber vials using a 0.45-µm nylon filter. The HPLC system (Lachrom Elite, Merck Hitachi, Darmstadt, Germany) was equipped with an autosampler (Model L-2200), a quaternary pump (Model L-2130), a column oven (Model L-2300) and a diode array detector (Model L-2450). A reversed-phase C30 YMC-Pack column (250 x 4.6 mm, 5-µm particle size, Merck, Darmstadt, Germany) was used. The injection volume was 60 µL and the oven temperature was 4 ºC. The mobile phase consisted in acetonitrile, methanol containing 0.05 M ammonium acetate and methylene chloride 75:20:5 (v/v/v) which, in turn, contained 0.1% butylated hydroxytoluene and 0.05% triethylamine. The flow rate was 1.5 mL/min. Detection was done at 450 nm. Identification of peaks was confirmed using the standards of major compounds. The total carotenoid concentration was also quantified in a multiplate spectrum reader (Multiskan Spectrum, Thermo Fisher

241 Scientific, Finland). The resuspended sample (0.5 ml) was mixed with 2.5 mL of the
242 mobile phase and measured within the 300-500 nm wavelength range. The results were
243 expressed as μg of total carotenoids per g of persimmon.
244
245 **Statistical analysis**
246 Statistical analyses were performed using STATGRAPHICS Plus 4.1 (Manugistic Inc.,
247 Rockville, MD, USA). Specific differences among treatments were determined by least
248 significant differences (LSD) when the analysis of variance (ANOVA) showed a
249 significant *F*-value. Significant differences were defined at $p \leq 0.05$.
250
251 **RESULTS AND DISCUSSION**
252 **Color and firmness**
253 Color *L** and *a** values were selected as the most suitable parameters to measure fresh-
254 cut persimmon surface browning. Fig. 1 shows the color change of the samples for the
255 first experiment, with a decrease in *L** and an increase in *a** as storage at 5 ºC was
256 prolonged. In the control samples (water-dipped), the application of the different
257 controlled atmospheres reduced fresh-cut persimmon enzymatic browning, as observed
258 by the higher *L** and the lower *a** values if compared to those stored in air (Atm-A),
259 where Atm-D (5 kPa O_2 + 10 kPa CO_2) was the most effective. The effectiveness of a
260 similar atmosphere to control browning has been reported in fresh-cut papaya
261 (Waghmare et al., 2013) or mangosteen (Manurakchinakorn et al., 2011), while an
262 atmosphere of 2 kPa O_2 + 12 kPa CO_2 has also been shown to maintain higher *L** and
263 lower *a** than the atmospheric conditions in fresh-cut 'Fuyu' persimmons over 8 storage
264 days at 5 ºC (Wright and Kader, 1997b).

When persimmon slices were dipped in antibrowning solutions, enzymatic browning diminished, whereas the combination of antibrowning agents and the different controlled atmospheres did not further reduce browning. On the contrary, the application of high CO_2 concentrations induced darkening in some tissue areas, which differed from that observed as enzymatic browning due to the cutting process. Several studies have described this tissue darkening as a flesh disorder in whole persimmons, known as 'flesh browning' (Novillo et al., 2014a, 2014b). Even though the cause of this disorder remains unknown, it has been related to pre-harvest nutritional deficiencies, mechanical injury during the postharvest period and the post-application of high CO_2 atmospheres to eliminate astringency (Besada et al., 2010; Zavrtanik et al., 1999). In recent studies, Novillo et al. (2014a, 2014b) reported that the incidence and severity of 'flesh browning' in 'Rojo Brillante' persimmons was greater the longer the CO_2 exposure time taken to remove astringency. This correlated with an accumulation of superoxide anion and H_2O_2, which suggests the implication of oxidative stress in this postharvest disorder of persimmon fruits. In our work, 'flesh browning' increased as the CO_2 concentration increased, but mainly in those samples dipped in antibrowning agents, where the persimmon slices that were dipped in 10 g L^{-1} CA and placed in Atm-C (21 kPa O_2 + 20 kPa CO_2) were those that displayed the most 'flesh browning'. Gorny et al. (2002) also observed accelerated tissue browning, as well as necrosis, in fresh-cut pears when they applied similar controlled atmospheres (18.8 kPa O_2 + 10 kPa CO_2 and 16.7 kPa O_2 + 20 kPa CO_2, balance N_2). In their work, substantial CO_2 injury occurred in a dose-responsive manner, and damage occurred earlier and more severely in the 20 kPa CO_2-treated slices than in the 10 kPa CO_2-treated slices.

As the application of atmospheres with high CO_2 concentrations induced 'flesh browning' of fresh-cut 'Rojo Brillante' persimmons, a second experiment was designed

290 in which an atmosphere with 5 kPa O_2 and without CO_2 (Atm-E) was compared with
291 Atm-D (5 kPa O_2 + 10 kPa CO_2) and Atm-A (air conditions) in persimmon fruits
292 harvested at two MS and dipped in 10 g L^{-1} AA or 10 g L^{-1} CA. The color L* and a*
293 values decreased and increased, respectively, in association with fresh-cut persimmon
294 browning during storage (Fig. 2 and 3). The tested controlled atmospheres only reduced
295 enzymatic browning in the control samples (water-dipped) processed at MS1, whereas
296 the samples harvested late in the season (MS2) and/or dipped in antibrowning solutions
297 were not systematically affected by atmosphere composition. In the control samples
298 with MS1, Atm-D (5 kPa O_2 + 10 kPa CO_2) proved to be the most effective application
299 to prevent enzymatic browning. However for both MSs, the persimmon slices packed in
300 this atmosphere presented some tissue areas with the 'flesh browning' disorder, whereas
301 Atm-E (5 kPa O_2) completely prevented this disorder from appearing, which confirms
302 the effect observed in experiment 1. Although very few studies have linked the use of
303 antioxidants with low O_2 atmospheres, some works have shown a synergic effect that
304 reduced browning in fresh-cut fruits. Thus the application of 10 g L^{-1} AA, and in
305 association with 0.4 kPa O_2, prolonged the shelf life of carambola slices by up to 12
306 days at 4.1 ºC (Teixera et al., 2008). Yet the application of antibrowning agents in the
307 present work significantly decreased enzymatic browning, but overwhelmed the effect
308 of the studied controlled atmospheres, which corroborates the results obtained in
309 experiment 1. The effectiveness of the antioxidants was also less marked in the
310 persimmons harvested late in the season, which confirms previous findings in fresh-cut
311 'Rojo Brillante' persimmons (Sanchís et al., 2015).

312 The controlled atmospheres and the antibrowning dips tested in experiment 1
313 induced tissue softening of persimmon slices if compared to the control samples stored
314 in the air atmosphere (Fig. 4). In experiment 2, persimmon fruits were harvested at

315 higher maturity than in experiment 1. Firmness diminished after processing with an
316 average firmness loss of 14% and 41% for MS1 and MS2, respectively, after 9 days at 5
317 ºC (Fig. 5). This indicates the importance of firmness at harvest for maintaining sound
318 firmness during storage. The application of antibrowning agents did not affect fruit
319 firmness in the persimmon fruits processed with MS1, but the firmness of the
320 antioxidant dipped-samples was significantly lower in the fruits processed with MS2
321 (average value of 24 ± 7 N) than in the water-dipped samples (average value of 32 ± 8
322 N), as observed in experiment 1. Fruit firmness reduced by acid solutions has also been
323 reported in some fresh-cut fruits, such as pears (Oms-Oliu et al., 2006), apples (Rojas-
324 Graü et al., 2007) and persimmons (Sanchís et al., 2015). Several works have described
325 that the use of additives that alter the surface pH of fresh-cut products (e.g. citric and
326 ascorbic acid) does not only affects the PPO activity, but it also modulates cell wall
327 metabolism and texture (Knee, 1982; Pinheiro and Almeida, 2008; Gomes et al., 2010).
328 These works show that acidification can be detrimental to texture of fresh-cut products
329 by increasing water solubility of pectins. Thus, pectin solubilization was higher in pear
330 slices dipped in solutions at pH 3.0 than in slices treated at pH 7.0 (Gomes et al., 2010)
331 and in tomato pericarp disk dipped in solutions at pH 4.0 than at pH 7.0 (Pinheiro and
332 Almeida, 2008). Furthermore, the effect of pH in tomato pericarp firmness was more
333 pronounced as maturity stage increased. In all these studies, softening was well
334 correlated with pectin disassembly at low pH values. In our work, the pH of the CA and
335 AA antibrowning solutions were 2.5 and 3.0, respectively, which could explain tissue
336 softening. On the other hang although low O_2 atmospheres are reported to reduce fruit
337 softening by reducing the synthesis of wall degrading enzymes (Knee, 1982), the tested
338 controlled atmospheres did not prevent the fruit softening of persimmon slices, probably
339 due to the low pH of the antibrowning solutions. Similar results have been reported for

fresh-cut pears (Gorny et al., 2002), bananas (Vilas-Boas et al., 2006) or apples (Rojas-Graü et al., 2007) packed in low O_2 and high CO_2 (10-20 kPa) atmospheres.

Visual quality

Fig. 6 presents the visual quality of the fresh-cut persimmons processed in the two MSs and stored for 9 days at 5 ºC in the atmospheres tested in experiment 2. The control samples (water-dipped) were evaluated as poor or inedible by storage day 2, independently of the atmosphere tested and the MS at harvest. This shows that low O_2, either combined or not with high CO_2 conditions, does not suffice to control enzymatic browning in fresh-cut 'Rojo Brillante' persimmons. When 10 g L^{-1} AA was applied, the samples stored in Atm-E (5 kPa O_2) and Atm-A (air) reached the limit of marketability by days 7 and 9 for MS1 and MS2, respectively. However, the samples placed in Atm-D (5 kPa O_2 + 10 kPa CO_2) were either below that limit by day 5 for the MS1 persimmon fruits or achieved a 5-day commercial shelf life for the MS2 fruits. For the 10 g L^{-1} CA-treated samples, Atm-E (5 kPa O_2) maintained good visual quality for 9 storage days at 5 ºC for both MSs. The fruits stored in either air (Atm-A) or 5 kPa O_2 + 10 kPa CO_2 (Atm-D) reached the limit of marketability by storage day 7 at 5 ºC in MS1, whereas those processed with MS2 were still marketable at the end of the study, regardless of the atmosphere tested. The shorter commercial shelf life of the persimmon slices placed in Atm-D (5 kPa O_2 + 10 kPa CO_2), if compared to Atm-E (5 kPa O_2), can be attributed to the 'flesh browning' incidence in fruits which, despite not being as severe as in experiment 1 for the samples placed in Atm-B (21 kPa O_2 + 10 kPa CO_2) and Atm-C (21 kPa O_2 + 20 kPa CO_2), also affected the visual quality of the fresh-cut persimmons. The difference between enzymatic browning in the control samples and 'flesh browning' in the antibrowning-treated samples for the different controlled

365 atmospheres studied is shown in Fig. 7. Therefore, these results confirm that CO_2
366 accumulation in the packaging of fresh-cut 'Rojo Brillante' persimmons should be
367 avoided in order to prolong their commercial shelf life. 'Flesh browning' incidence was
368 also affected by MS, which was higher in the fruits with MS2. Recent studies done with
369 whole 'Rojo Brillante' persimmons have also indicated that superoxide anion levels
370 gradually increased with persimmon maturation after removal astringency (Novillo et
371 al., 2014a). Similarly, oxidative stress associated with fruit ripening has also been
372 reported in other species, such as mango (Singh and Dwivedi, 2008), peach (Camejo et
373 al., 2010) or papaya (Couto et al., 2012).
374
375 **Bioactive compounds**
376 Fruit stage at harvest is one of the major factors that affects the nutritional value of
377 fruits. Prolonged maturity may increase, decrease or have no effect on specific
378 nutritional compounds, depending on the compound, and on the species or cultivars. In
379 this work, the fruits processed in MS2 obtained higher values for TVC and total
380 carotenoids, but lower values for TPC and radical scavenging activity than those
381 processed in MS1 (Table 1). Similar trends in TVC, radical scavenging activity and
382 total carotenoids have been observed for fresh-cut 'Rojo Brillante' as being affected by
383 MS at harvest, but not for total phenolic content (Sanchís et al., 2015). In all cases, the
384 concentrations obtained herein fell within the same range as those obtained in other
385 studies for non astringent persimmon cultivars and astringent cultivar 'Rojo Brillante' at
386 similar harvest periods (Del Bubba et al., 2009; Sanchís et al., 2015; Wright and Kader,
387 1997a). Processing, antibrowning dips and controlled atmosphere storage had no clear
388 effect on the different bioactive compounds tested, and the differences observed
389 between treatments could be attributed to biological variation. The results that reflect

390 phytonutrient stability or the effectiveness of postharvest treatments on the nutritional
391 value of minimally processed fruits and vegetables generally differ according to the fruit
392 commodity and processing conditions. Some works have reported that antibrowning
393 agents, such as AA and CA, increase the level of ascorbic acid and help maintain the
394 TPC of fresh-cut apples (Cocci et al., 2006), kiwifruits (Antunes et al., 2010) and
395 mangoes (Robles-Sánchez et al., 2013; Siddiq et al., 2013) for 8-12 days at 4 ºC.
396 However in recent works, no clear effect of antibrowning dips based on AA and/or CA
397 on total vitamin C, and on the radical scavenging activity of fresh-cut 'Rojo Brillante'
398 persimmon, was observed (Sanchís et al., 2015). The use of low O_2 atmospheres has
399 been generally reported to reduce vitamin C loss by inhibiting its oxidation, whereas
400 high CO_2 has been described to cause degradation by stimulating the oxidation of
401 ascorbic acid to dehydroascorbic acid (Gil and Kader, 2008). Thus high O_2 or CO_2
402 concentrations induced more marked vitamin C losses in fresh-cut pears (Oms-Oliu et
403 al., 2008) and strawberries (Odriozola-Serrano et al., 2010). However in fresh-cut
404 'Fuyu' persimmons, storage in low O_2 (2 kPa) and/or high CO_2 (12 kPa) controlled
405 atmospheres had no significant effect on the changes noted in total ascorbic acid content
406 (Wright and Kader, 1997a).

407 Individual carotenoids were also analyzed and the results are shown in Table 2.
408 The major carotenoids detected were β-cryptoxanthin and β-carotene. Although some
409 significant differences were found among treatments, the results were variable, which
410 makes it difficult to conclude the effectiveness of atmosphere conditions and
411 antibrowning solutions on these carotenoids in fresh-cut persimmons. Only the control
412 samples with MS1 stored in Atm-D (5 kPa O_2 + 10 kPa CO_2) presented higher
413 concentrations of both carotenoids at the end of the 9-day storage. After 8 storage days
414 at 5 ºC, Wright and Kader (1997b) reported a drop in the individual carotenoids content

in 'Fuyu' persimmon slices stored in both 2 kPa O_2 and 21 kPa O_2 + 12 kPa CO_2, but this loss was not that significant for the slices stored under the 2 kPa O_2 + 12 kPa CO_2 conditions. Overall, no significant losses in provitamin A were seen before the slices reached their limit of marketability.

CONCLUSIONS

The combination of high O_2 (21 kPa) and elevated CO_2 (10 or 20 kPa) did not prevent enzymatic browning and softening of fresh-cut 'Rojo Brillante' persimmons, and high CO_2 concentrations induced 'flesh browning' on tissue. Antibrowning agents (10 g L^{-1} AA or 10 g L^{-1} CA) and Atm-E (5 kPa O_2, balance N_2) proved to be most effective combination to prevent enzymatic browning and to maintain visual quality above the limit of marketability for 9 days at 5 ºC for both the MSs studied. TVC, free radical scavenging activity, TPC and carotenoid content were affected by the MS at harvest, whereas processing, antibrowning dips and controlled atmosphere storage had no clear effect.

Future work will require the validation of modified atmosphere packaging that would assure low O_2 and CO_2 values to control both enzymatic and 'flesh browning' of fresh-cut 'Rojo Brillante' persimmon in order to develop the product at commercial scale, making special emphasis on sensory quality and shelf life.

ACKNOWLEDGEMENTS

This work has been funded by the Instituto Nacional de Investigacion y Tecnologia Agraria y Alimentaria (INIA) through Project RTA2009-00135-00-00 and the European Union (FEDER Programme). Elena Sanchis' doctorate program is also supported by the

439 INIA. The authors thank the Protected Designation of Origin (PDO) Ribera del Xúquer
440 Kaki for kindly providing persimmon fruits.

441

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560 **Table 1.** Effect on controlled atmosphere storage at 5 ºC and antibrowning dipps on total vitamin C, free radical scavenging activity, total
561 phenolic content and total carotenoids of sliced 'Rojo Brillante' persimmons harvested at two maturity stage (MS).

			Total vitamin C (mg AA/100 g)				Free radical scavenging activity (g /kg DPPH•)				Total phenolic content (mg GA/100 g)				Total carotenoids (µg /100 g)			
Day	Atm		MS1		MS2		MS1		MS2		MS1		MS2		MS1		MS2	
0			183.3 ± 35.0	B	354.6 ± 40.4	A	253.9 ± 18.0	A	145.1 ± 17.3	B	8.9 ± 0.4	A	5.3 ± 0.4	B	189.4 ± 63.9	A	284.4 ± 10.3	B
2	A	10 g L^{-1} AA	242.8 ± 62.0	aA	347.1 ± 14.1	aA	113.1 ± 4.0	dB	177.3 ± 13.9	dA	7.2 ± 0.5	abA	6.3 ± 0.5	aA	200.7 ± 42.2	bcA	256.9 ± 74.3	abA
		10 g L^{-1} CA	184.9 ± 40.4	abA	191.8 ± 20.7	bcdA	318.8 ± 30.2	bcA	252.3 ± 35.9	cA	7.2 ± 0.5	abA	6.4 ± 0.5	aA	165.6 ±15.3	cA	160.4 ± 0.2	bA
		CTL	192.9 ± 18.3	abA	120.0 ± 17.0	dB	367.0 ± 35.7	abA	333.0 ± 16.0	bA	8.8 ± 0.6	aA	7.3 ± 0.6	aA	226.3 ± 88.2	bA	326.9 ± 87.9	aA
	D	10 g L^{-1} AA	167.8 ± 31.6	abA	177.3 ± 31.8	cdA	277.0 ± 12.6	cB	403.9 ± 23.6	aA	8.2 ± 0.5	abA	7.3 ± 0.6	aA	185.7 ± 32.0	cA	203.8 ± 53.3	abA
		10 g L^{-1} CA	135.0 ± 17.2	bA	150.3 ± 19.2	cdA	438.5 ± 23.9	aA	242.3 ± 16.2	cB	7.8 ± 0.6	abA	7.5 ± 0.6	aA	144.6 ± 14.9	cB	220.5 ± 3.0	abA
		CTL	182.7 ± 30.5	abA	247.0 ± 26.9	abcA	442.6 ± 52.1	aA	250.9 ± 27.3	cB	7.2 ± 0.5	abA	7.1 ± 0.6	aA	222.3 ± 35.9	bcA	261.7 ± 26.4	abA
	E	10 g L^{-1} AA	192.7 ± 27.7	abA	317.5 ± 69.8	aA	374.2 ± 15.7	abA	418.7 ± 17.8	aA	7.7 ± 0.6	abA	6.6 ± 0.6	aA	168.7 ± 11.7	cA	227.6 ± 12.6	abA
		10 g L^{-1} CA	128.2 ± 9.4	bA	189.0 ± 40.0	bcdA	355.4 ± 18.6	bcA	176.4 ± 5.9	dB	7.4 ± 0.7	abA	7.2 ± 0.5	aA	130.3 ± 5.9	cA	152.4 ± 21.9	bA
		CTL	164.7 ± 23.7	abA	301.3 ± 80.2	abA	388.9 ± 27.8	abA	161.1 ± 12.1	dB	6.8 ± 0.6	bA	7.3 ± 0.6	aA	333.5 ± 18.5	aA	251.1 ± 12.6	abB
5	A	10 g L^{-1} AA	162.8 ± 30.2	abA	212.1 ± 31.0	cdeA	307.9 ± 48.0	aA	271.4 ± 16.3	bA	7.2 ± 0.6	bcdA	5.1 ± 0.4	cB	185.1 ± 42.4	abA	280.4 ± 29.5	aA
		10 g L^{-1} CA	149.5 ± 17.4	bA	275.2 ± 71.8	bcdeA	294.8 ± 18.1	aB	429.5 ± 51.3	aA	7.2 ± 0.5	cdA	7.5 ± 0.4	aA	200.3 ± 0.3	abA	295.8 ± 41.8	aA
		CTL	228.9 ± 28.6	aA	137.2 ± 10.5	eB	323.2 ± 22.3	aA	317.6 ± 25.7	bA	6.5 ± 0.4	deA	7.3 ± 0.6	abA	262.4 ± 11.6	aA	262.7 ± 28.4	aA
	D	10 g L^{-1} AA	192.4 ± 46.3	abA	147.6 ± 11.5	deA	302.8 ± 36.1	aA	273.9 ± 13.9	bA	6.6 ± 0.5	deA	7.8 ± 0.6	aA	169.4 ± 7.6	abA	256.9 ± 58.4	aA
		10 g L^{-1} CA	190.7 ± 12.3	abA	427.8 ± 57.9	aA	299.1 ± 20.9	aB	465.1 ± 49.5	aA	8.9 ± 0.5	aA	8.1 ± 0.6	aA	117.6 ± 67.0	bA	257.4 ± 23.1	aA
		CTL	129.8 ± 16.2	bB	293.1 ± 49.1	abcA	340.7 ± 16.3	aA	408.0 ± 37.6	aA	8.1 ± 0.6	abcA	6.0 ± 0.5	bcB	118.2 ± 69.8	bA	267.0 ± 10.3	aA
	E	10 g L^{-1} AA	147.7 ± 11.7	bB	405.8 ± 51.0	abA	151.6 ± 20.3	bB	274.4 ± 21.0	bA	8.7 ± 0.6	abA	7.0 ± 0.6	abA	230.6 ± 72.3	abA	197.1 ± 21.1	aA
		10 g L^{-1} CA	233.9 ± 38.4	aA	267.5 ± 65.4	bcdeA	159.5 ± 13.1	bB	215.4 ± 5.2	bA	7.0 ± 0.5	cdeA	5.4 ± 0.4	cB	111.6 ± 11.4	bB	302.8 ± 13.9	aA
		CTL	194.0 ± 27.5	abA	280.9 ± 59.4	bcdA	292.9 ± 5.9	aA	224.3 ± 11.3	bB	5.6 ± 0.4	eA	6.0 ± 0.5	bcA	186.2 ± 0.4	abA	305.5 ± 53.9	aA
9	A	10 g L^{-1} AA	158.4 ± 17.7	abB	257.9 ± 38.3	abA	332.8 ± 28.5	bcA	130.2 ± 7.9	fB	8.3 ± 0.5	aA	6.2 ± 0.4	cdeB	120.7 ± 8.5	abB	275.4 ± 21.6	bcA
		10 g L^{-1} CA	165.7 ± 60.8	abA	183.2 ± 27.0	bA	232.6 ± 20.8	dB	484.4 ± 35.7	aA	5.3 ± 0.2	dB	7.1 ± 0.4	bcdA	152.3 ± 136.6	aA	292.7 ± 34.2	bcA
		CTL	160.5 ± 19.8	abA	277.7 ± 62.0	abA	379.7 ± 22.2	abA	393.3 ± 19.4	bA	7.1 ± 0.5	abcA	7.9 ± 0.4	abA	354.6 ± 0.7	bA	215.6 ± 0.3	bcB
	D	10 g L^{-1} AA	107.1 ± 38.5	abB	224.8 ± 20.2	abA	383.6 ± 19.4	abA	300.9 ± 21.8	cB	7.4 ± 0.6	abcA	8.4 ± 0.4	aA	260.7 ± 63.3	aA	223.6 ± 6.5	cA
		10 g L^{-1} CA	86.6 ± 16.4	bB	286.1 ± 52.2	abA	230.4 ± 23.0	dB	388.9 ± 23.2	bA	6.9 ± 0.5	bcA	6.5 ± 0.4	cdeA	233.8 ± 6.9	aB	431.5 ± 0.5	aA
		CTL	91.1 ± 11.6	bB	272.8 ± 32.7	abA	232.7 ± 15.3	dA	202.4 ± 26.1	deA	6.5 ± 0.5	cdA	7.1 ± 0.5	bcA	161.3 ± 44.1	abA	343.2 ± 3.0	abA
	E	10 g L^{-1} AA	133.9 ± 28.2	abB	301.8 ± 40.4	aA	355.6 ± 23.1	abcA	170.4 ± 9.0	efB	8.0 ± 0.4	abA	5.7 ± 0.5	eB	187.2 ± 50.2	abA	236.6 ± 27.0	cA
		10 g L^{-1} CA	120.0 ± 11.5	abA	191.7 ± 28.0	bA	409.0 ± 30.3	aA	211.5 ± 20.5	deB	6.9 ± 0.4	bcA	5.4 ± 0.5	deA	213.9 ± 17.7	abA	272.9 ± 80.7	bcA
		CTL	198.6 ± 15.1	aA	219.1 ± 8.7	abA	288.8 ± 8.2	cdA	238.1 ± 28.5	cdA	7.8 ± 0.3	abA	5.8 ± 0.5	eB	249.2 ± 2.6	aA	321.2 ± 22.9	bcA

562 Atm-A = air; Atm-D = 5 kPa O2 + 10 kPa CO2; Atm-E = 5 kPa O2; AA = Ascorbic acid; CA = Citric acid.
563 Values are mean ± standard error
564 Small letters show significant differences among treatments within each storage time by the LSD test ($p \leq 0.05$).
565 Capital letters show significant differences between MSs by the LSD test ($p \leq 0.05$).
566

Table 2. Effect on controlled atmosphere storage at 5 ºC and antibrowning dipps on β-cryptoxanthin and β-carotene content of fresh-cut 'Rojo Brillante' persimmons harvested at two maturity stage (MS).

			β-cryptoxanthin (µg /100 g FW)				β-carotene (µg /100 g FW)			
Day	Atm		MS1		MS2		MS1		MS2	
0			74.67 ± 3.72	A	53.89 ± 2.31	B	73.23 ± 0.89	B	245.87 ± 1.23	A
2	A	10 g L^{-1} AA	64.78 ± 0.60	bcA	36.06 ± 0.34	bB	62.83 ± 0.55	abB	117.92 ± 1.26	abA
		10 g L^{-1} CA	121.39 ± 1.92	abA	36.66 ± 2.81	bB	63.70 ± 0.99	abB	135.19 ± 1.56	aA
		CTL	170.92 ± 2.08	aA	60.85 ± 3.07	bB	57.83 ± 1.10	abA	87.69 ± 0.73	abA
	D	10 g L^{-1} AA	66.76 ± 1.25	bcB	189.62 ± 0.64	aA	86.49 ± 1.15	abA	96.91 ± 0.31	abA
		10 g L^{-1} CA	82.52 ± 2.10	bcB	192.41 ± 1.32	aA	55.39 ± 1.07	abB	100.46 ± 0.21	abA
		CTL	53.52 ± 1.07	cB	147.40 ± 2.56	aA	45.08 ± 0.71	bB	84.33 ± 1.08	abA
	E	10 g L^{-1} AA	112.80 ± 0.22	abcB	146.60 ± 1.18	aA	70.50 ± 0.72	abA	78.08 ± 1.25	abA
		10 g L^{-1} CA	90.15 ± 1.01	bcB	155.26 ± 1.09	aA	45.61 ± 0.78	bA	58.46 ± 0.92	bA
		CTL	113.19 ± 1.57	abcB	184.46 ± 2.60	aA	101.20 ± 1.42	aA	80.47 ± 0.85	abA
5	A	10 g L^{-1} AA	129.50 ± 2.65	abB	180.28 ± 1.14	dA	79.87 ± 0.42	aA	81.62 ± 0.57	abA
		10 g L^{-1} CA	116.08 ± 1.98	abB	219.71 ± 1.06	abA	105.69 ± 0.26	aA	103.30 ± 0.90	aA
		CTL	137.32 ± 0.85	aB	213.83 ± 1.37	bcA	91.55 ± 0.35	aA	98.74 ± 0.49	aA
	D	10 g L^{-1} AA	116.36 ± 0.73	aB	144.87 ± 2.05	fA	74.58 ± 1.69	aA	61.85 ± 0.56	bA
		10 g L^{-1} CA	125.30 ± 2.58	abB	184.64 ± 1.35	dA	77.71 ± 0.32	aB	104.17 ± 0.63	aA
		CTL	126.70 ± 1.93	aB	167.39 ± 1.88	efA	82.70 ± 0.43	aA	79.56 ± 0.64	abA
	E	10 g L^{-1} AA	136.42 ± 0.65	abB	191.49 ± 2.99	cdA	75.86 ± 1.24	aA	89.47 ± 0.72	aA
		10 g L^{-1} CA	143.10 ± 0.73	abB	245.98 ± 1.94	aA	41.25 ± 0.93	aB	100.17 ± 0.35	aA
		CTL	69.68 ± 0.91	abB	230.01 ± 2.11	abA	38.76 ± 0.16	aB	88.73 ± 0.76	aA
9	A	10 g L^{-1} AA	143.10 ± 1.01	bB	189.11 ± 1.08	aA	41.25 ± 0.27	cB	90.67 ± 0.91	aA
		10 g L^{-1} CA	69.68 ± 2.31	eB	176.89 ± 1.82	aA	38.76 ± 0.31	cB	73.75 ± 0.20	aA
		CTL	85.78 ± 1.62	dB	205.98 ± 0.72	aA	38.41 ± 0.68	cB	80.94 ± 1.25	aA
	D	10 g L^{-1} AA	118.53 ± 0.34	cB	190.99 ± 2.20	aA	50.36 ± 0.17	cA	71.61 ± 1.35	aA
		10 g L^{-1} CA	80.70 ± 2.21	deB	195.19 ± 0.52	aA	164.98 ± 0.23	bA	75.38 ± 0.27	aB
		CTL	198.47 ± 0.71	aB	229.78 ± 1.02	aA	233.82 ± 1.71	aA	111.33 ± 2.37	aB
	E	10 g L^{-1} AA	82.56 ± 0.42	deB	140.68 ± 1.72	aA	157.28 ± 0.45	bA	76.18 ± 1.14	aB
		10 g L^{-1} CA	46.78 ± 1.16	fB	164.37 ± 2.74	aA	122.14 ± 1.17	bA	78.86 ± 0.95	aB
		CTL	136.52 ± 1.52	bB	144.21 ± 0.65	aA	153.91 ± 0.37	bA	83.02 ± 0.45	aB

Atm-A = air; Atm-D = 5 kPa O2 + 10 kPa CO2; Atm-E = 5 kPa O2; AA = Ascorbic acid; CA = Citric acid.
Values are mean ± standard error
Small letters show significant differences among treatments within each storage time by the LSD test ($p \leq 0.05$).
Capital letters show significant differences between MSs by the LSD test ($p \leq 0.05$).

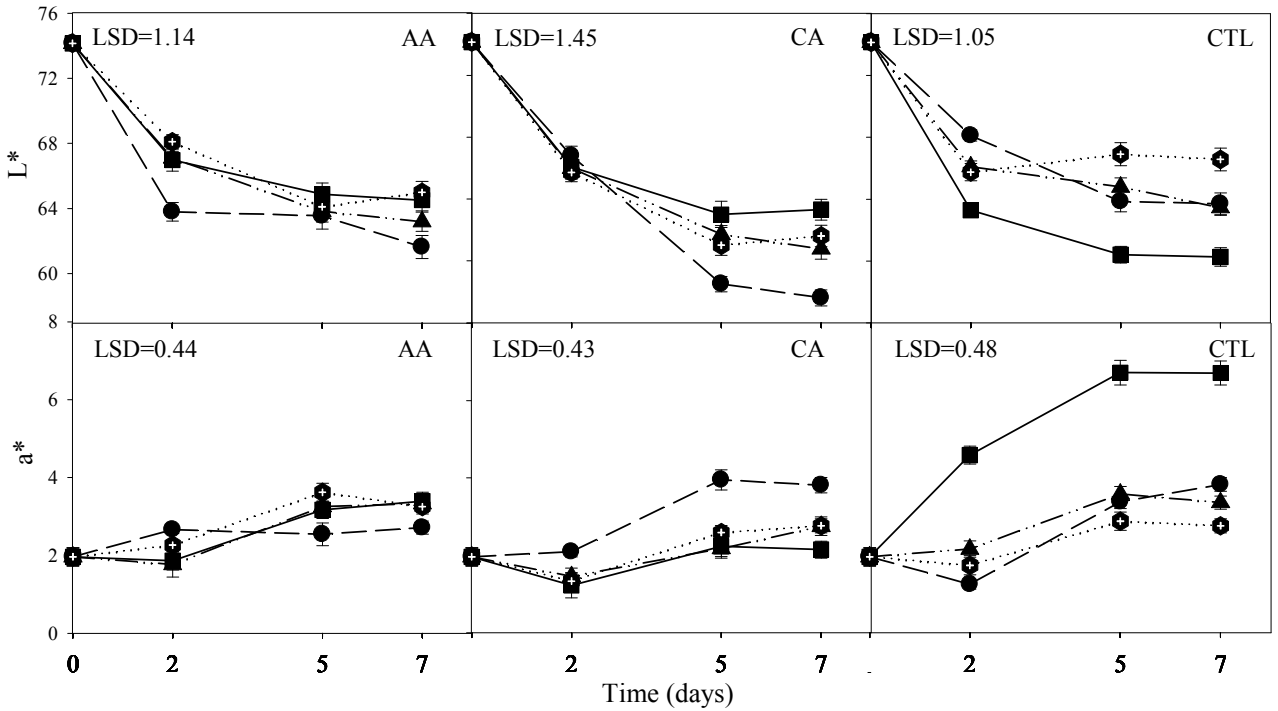

Figure 1. Color L* and a* changes in fresh-cut 'Rojo Brillante' persimmons stored in controlled atmospheres Atm-A (—■—), Atm-B (—▲··), Atm-C (—●·) and Atm-D (··✪··) for 7 days at 5 ºC and dipped in 10 g L^{-1} ascorbic acid (AA), 10 g L^{-1} citric acid (CA) or water (CTL). Atm-A = air; Atm-B = 21 kPa O_2 + 10 kPa CO_2; Atm-C = 21 kPa O_2 + 20 kPa CO_2; Atm-D = 5 kPa O_2 + 10 kPa CO_2. Vertical bars are standard errors (n=12).

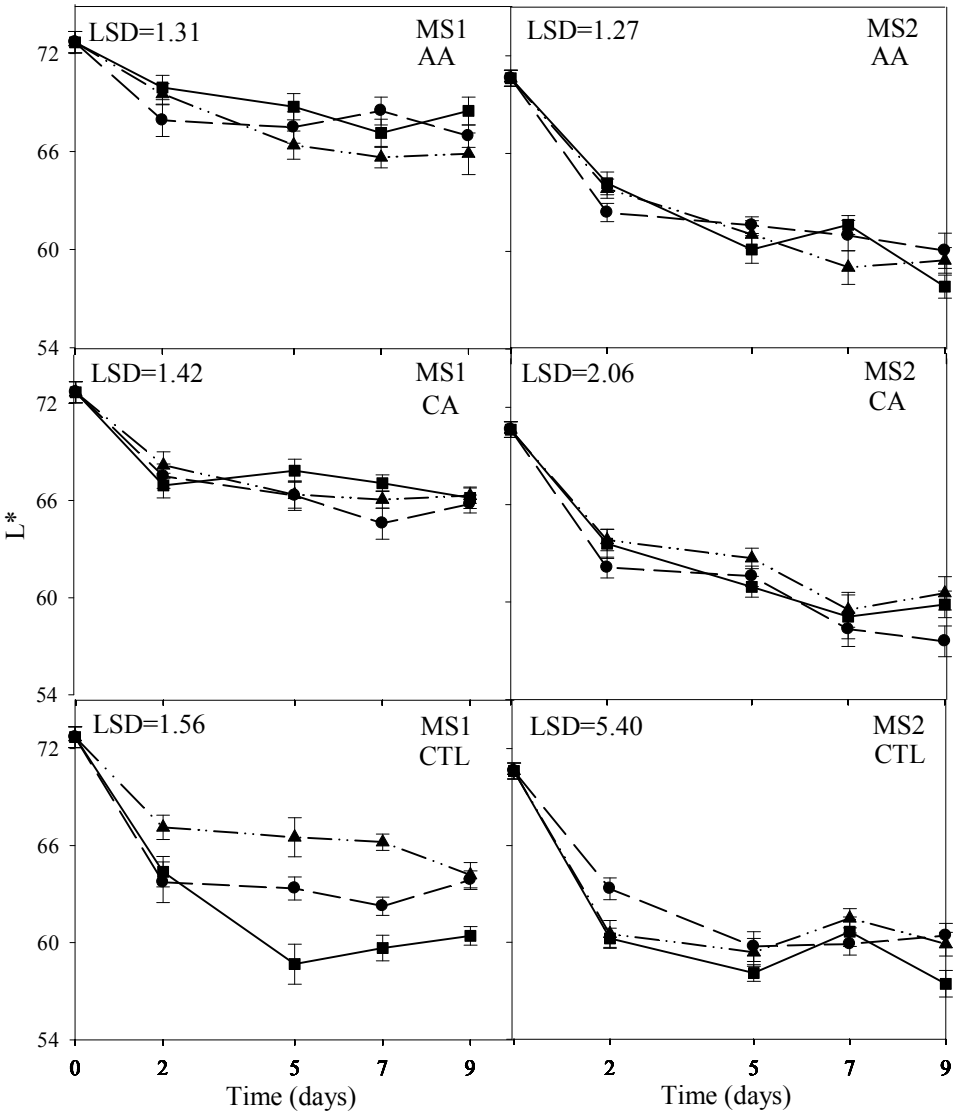

Figure 2. Color L* changes in fresh-cut 'Rojo Brillante' persimmons stored in controlled atmospheres Atm-A (—■—), Atm-D (—▲··) or Atm-E (—● ·) for 9 days at 5 ºC and dipped in 10 g L^{-1} ascorbic acid (AA), 10 g L^{-1} citric acid (CA) or water (CTL). Atm-A = air; Atm-D = 5 kPa O_2 + 10 kPa CO_2; Atm-E = 5 kPa O_2. Vertical bars are standard errors (n=12).

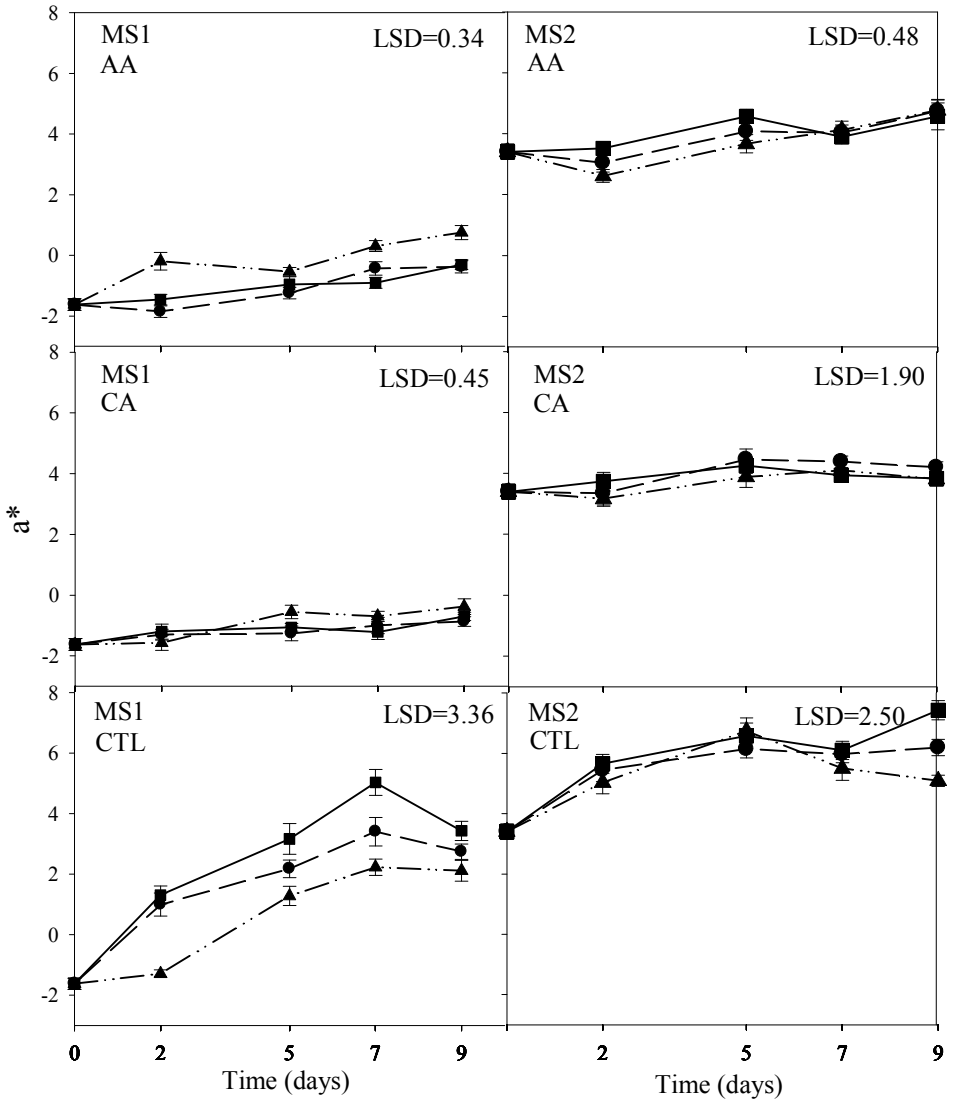

Figure 3. Color a* changes in fresh-cut 'Rojo Brillante' persimmons stored in controlled atmospheres Atm-A (—■—), Atm-D (—▲··) or Atm-E (—●· ·) for 9 days at 5 ºC and dipped in 10 g L^{-1} ascorbic acid (AA), 10 g L^{-1} citric acid (CA) or water (CTL). Persimmons were processed in two maturity stages (MS1 and MS2). Atm-A = air; Atm-D = 5 kPa O_2 + 10 kPa CO_2; Atm-E = 5 kPa O_2. Vertical bars are standard errors (n=12).

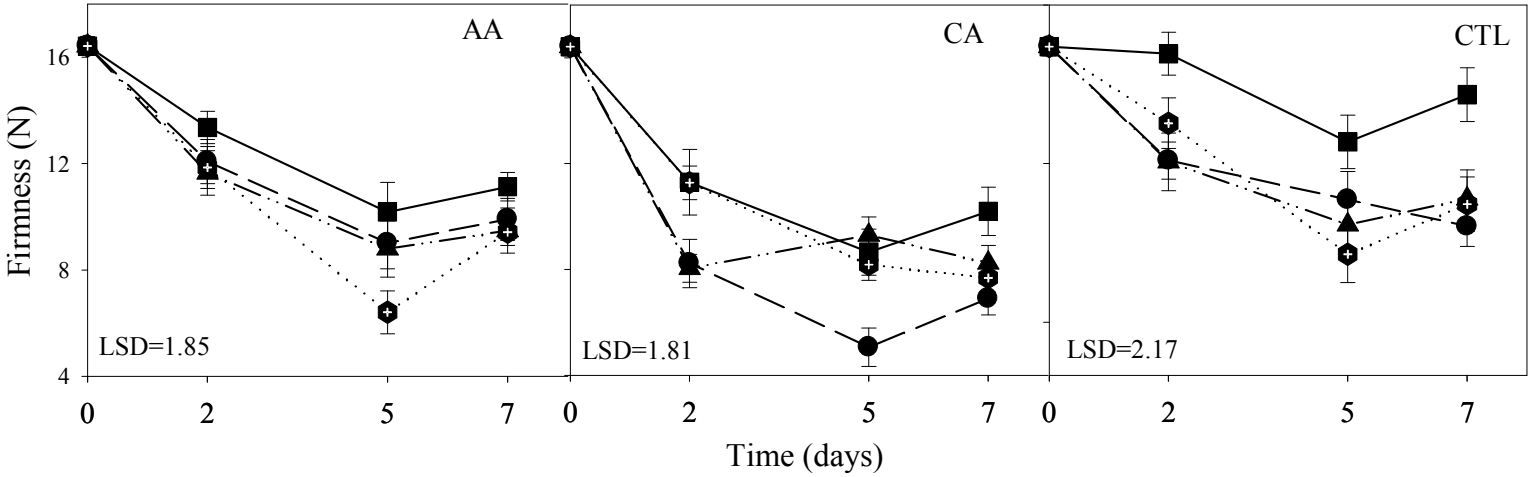

Figure 4. Firmness of fresh-cut 'Rojo Brillante' persimmons stored in controlled atmospheres Atm-A (—■—), Atm-B (—▲···), Atm-C ( ) and Atm-D (···●···) for 7 days at 5 ºC and dipped in 10 g L^{-1} ascorbic acid (AA), 10 g L^{-1} citric acid (CA) or water (CTL). Atm-A = air; Atm-B = 21 kPa O_2 + 10 kPa CO_2; Atm-C = 21 kPa O_2 + 20 kPa CO_2; Atm-D = 5 kPa O_2 + 10 kPa CO_2. Vertical bars are standard errors (n=12).

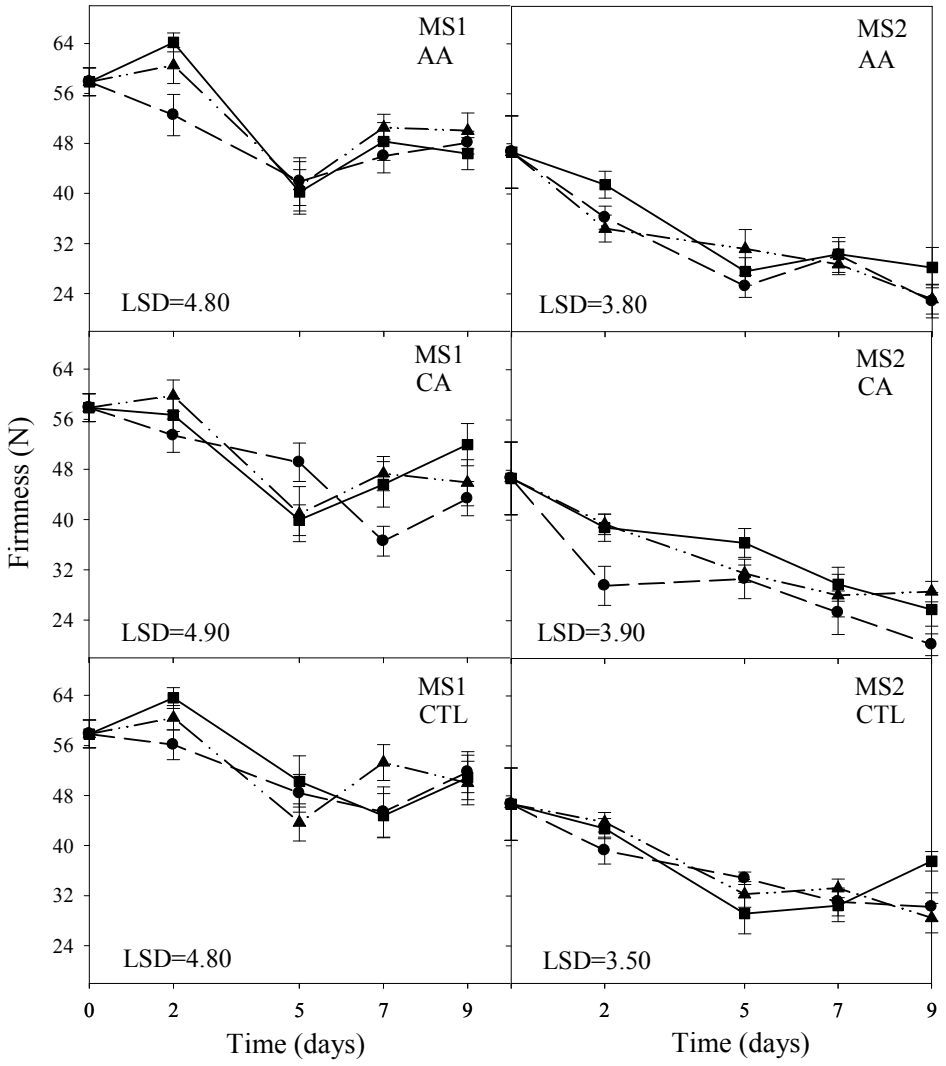

Figure 5. Firmness of fresh-cut 'Rojo Brillante' persimmons stored in controlled atmospheres Atm-A (—■—), Atm-D (—▲··) or Atm-E (—●· ·) for 9 days at 5 ºC and dipped in 10 g L^{-1} ascorbic acid (AA), 10 g L^{-1} citric acid (CA) or water (CTL). Persimmons were processed in two maturity stages (MS1 and MS2). Atm-A = air; Atm-D = 5 kPa O_2 + 10 kPa CO_2; Atm-E = 5 kPa O_2. Vertical bars are standard errors (n=12).

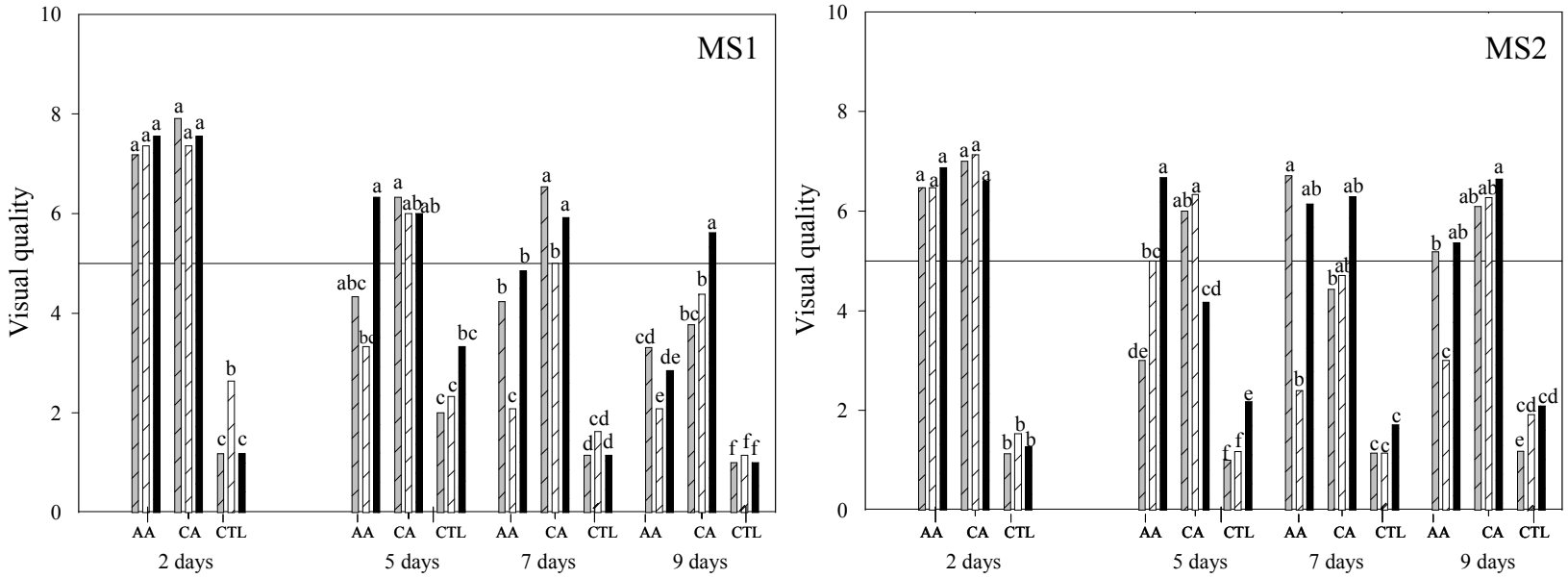

Figure 6. Visual quality of fresh-cut 'Rojo Brillante' persimmons stored for 9 days at 5 ºC in controlled atmospheres Atm-A (▨), Atm-D (▨) or Atm-E (■) and dipped in 10 g L^{-1} ascorbic acid (AA), 10 g L^{-1} citric acid (CA) or water (CTL). Persimmons were processed in two maturity stages (MS1 and MS2). Atm-A = air; Atm-D = 5 kPa O_2 + 10 kPa CO_2; Atm-E = 5 kPa O_2. Visual scale: 9 = excellent, just sliced; 7 = very good; 5 = good, limit of marketability; 3 = fair, limit of usability; and 1 = poor, inedible. The results are average values. Bars with different letters are significantly different at the 95% level (n=15).

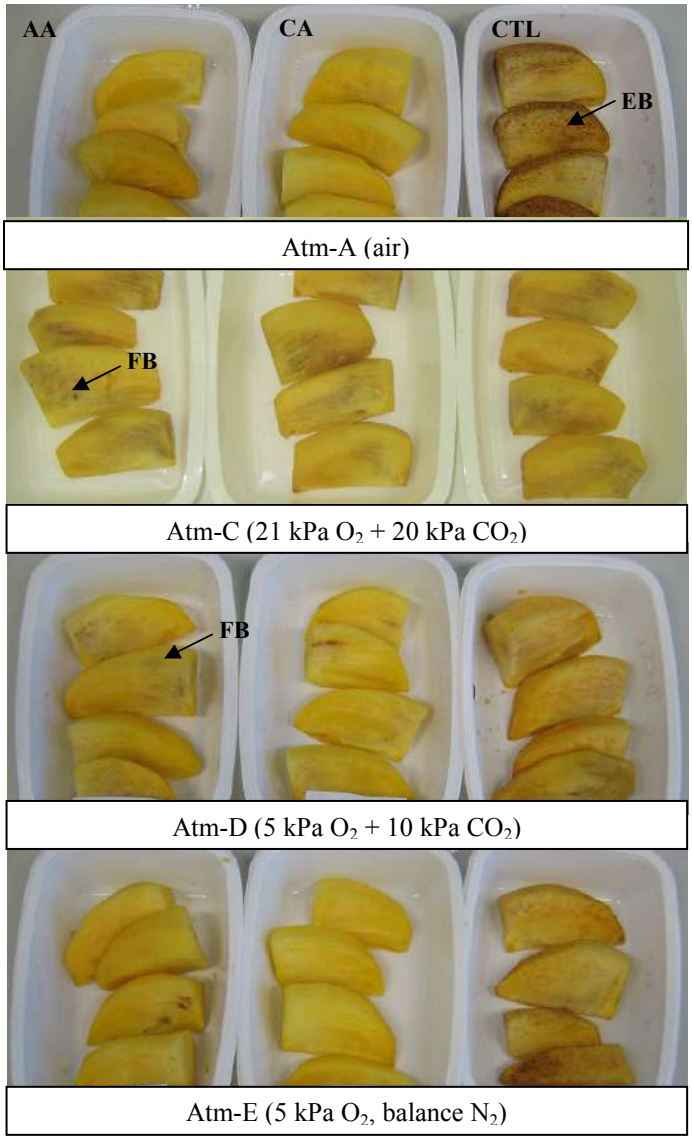

Figure 7. Fresh-cut 'Rojo Brillante' persimmons stored for 7 days at 5 ºC in different controlled atmospheres (Atm) and dipped in 10 g L^{-1} ascorbic acid (AA), 10 g L^{-1} citric acid (CA) or water (CTL). Arrows show the differences between 'enzymatic browning' (EB) and 'flesh browning' (FB).