Effect of High Carbon Dioxide or Gaseous Ozone Combined with MAP on the Chemical Composition of Organic Late-Season Table Grapes Scarlotta Seedless® during long-term storage

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Abstract

The aim of this study was to maintain the quality of organic table grapes and extend their shelf life for long-term storage by using organically approved methods. The effectiveness of the pretreatments with different concentrations of gaseous ozone (varying from 5 to 20 µL L^{-1}) or carbon dioxide (at 50 and 70%) followed by storage under modified atmosphere packaging (2% O_2: 5% CO_2: 93% N_2 MAP) were evaluated on late-season organic Scarlotta® grapes as alternatives to usual commercial SO_2 application. After 45 days of cold storage (CS), pretreatments with O_3 increased significantly total anthocyanins at the opposite of pretreatments with CO_2. Furthermore,

pretreatments with O_3 at 20 µL L^{-1} controlled concentration of acetaldehyde, preserved rachis chlorophyll content and skin color during CS.

Regarding cumulative decay incidence, it was reduced 5 to 6 fold by pretreatments with O_3 at 20 µL L^{-1} and CO_2, compared to control after shelf life (SL), however, pretreatments with CO_2 caused also organoleptic quality loss with strong stem browning and perceived off-flavor. The present experiment revealed the efficiency of pretreatment with O_3 at 20 µL L^{-1} to preserve initial sensory quality of organic Scarlotta® grapes and to control efficiently grape decay after CS and SL. Our results encourage confirming this postharvest alternative approach treatment in other cultivars and under commercial conditions.

Keywords: quality loss, organic table grapes, decay control, SO_2 alternative, shelf life, anthocyanin.

1 Introduction

Every year an important amount of table grapes is lost between harvest and consumption. Table grapes (*Vitis vinifera L.*) as non-climacteric fruits, are highly perishable after harvest and exposed to serious quality losses essentially due to water loss, which results in stem drying and browning, berry softening and pathological decay, mainly caused by gray mold (Valero et al., 2006; Baiano et al., 2007; Sanchez-Ballesta et al., 2007).

Gray mold due to *Botrytis cinerea* is the most economically important postharvest disease because of the damage caused in the harvest season and during storage, it is particularly severe in years when heavy rainfall occurs during fruit ripening, and can also develop at low temperature, shortening the duration of storage and marketing (Ciccarese et al., 2013).

Berry decay is another post-harvest affection, visible as “slip-skin”, separation of the skin from the flesh upon touch (Luvisi et al., 1992; Chervin et al., 2012). Moreover, the maturity and storage period increase significantly berry’s susceptibility to infection and decay symptoms during postharvest handling (Teles et al., 2014).

Commonly, the standard practice to control postharvest grape decay is achieved by using sulfur dioxide gas (SO_2); the grapes are fumigated either by repeated application of gas in storage room or by continuous release SO_2-generating pads in case of shippement period longer than 10 days or long retail handling (Chervin et al., 2012). This compound is registered as an adjuvant in different countries, and in spite of its efficacy for controlling gray mold; several problems are associated with its application. The main damages are: bleaching and other injuries to the rachis and berries, pitting of berries, off-flavor, excessive sulfite residues, corrosion of the equipment within storage facilities, worker safety, and air quality (Smilanick et al., 1990; Crisosto and Mitchell.

2002; Chervin et al., 2005; Zoffoli et al., 2008). For these reasons, this product has been removed from the Generally Recognized as Safe (GRAS) compound list by US Food and Drug Administration (US FDA) (Anon, 1986); whereas, it is not allowed as postharvest treatment on organic grapes in Europe and USA by EU regulation (EC) No 889/2008 and National Organization Program (NOP-USDA) respectively.

The demand for this fresh product with immaculate appearance, high sensory quality in terms of flavor, free of pathogens and chemical residue is a hard challenge considering the difficulties to conserve them with alternative safe treatments to SO_2. In order to fulfill this growing demand for fresh organic products, several efforts were focused to develop alternative strategies to control postharvest decay of organic table grapes; these strategies should be safe, effective, economical and compatible with commercial handling. As the use of GRAS type decontaminating agents, physical treatments and combined treatments (Romanazzi et al., 2012; Admane et al., 2015). The integration of two or more alternative treatments/means can be worthwhile than the use of single treatment (Wilson, 1997).

Ozone (O_3) was declared GRAS substance by the US FDA in 2001 (US FDA, 2001), and since that time it is being widely investigated and introduced into some commercial applications in food industry such as table grapes storage. O_3 is a highly reactive form of oxygen, naturaly present in the atmosphere and one of the most potent sanitizers against a wide spectrum of microorganisms (Khadre et al., 2001; Mlikota Gabler and Smilanick, 2001; Von Gunten, 2003). It has been extensively tested for the control of table grape decay (Cayuela et al., 2009; Sharpe et al., 2009; Mlikota Gabler et al., 2010; Smilanick et al., 2010). Many cold storage facilities in California have installed equipment that generates a constant low dose of O_3 (100 ppb day and 300 ppb night cycle) and it reduced the spread of gray mold and prolonged the storage of grapes

for several weeks (Smilanick et al., 2010). The risk of injury to table grapes from O_3 have been reported for the rachis after a treatment of 30 min with very high concentrations (5000 ppm) of O_3 (Mlikota Gabler et al., 2010). Therefore, ozone could be considered as a promising antimicrobial agent for the sanitation of grape surfaces to extent the storage period and shelf life.

In addition, postharvest treatment with short-term exposure to high carbon dioxide (CO_2) concentrations is an effective treatment to maintain quality and to control decay development in grapes (Crisosto et al., 2002b; Retamales et al., 2003; Sanchez-Ballesta et al., 2006, 2007; Teles et al., 2014). Furthermore, low concentration of O_2 (below 1%) induces anaerobic respiration, which leads to undesirable metabolic reactions, resulting in off-odors and off-flavors (Candir et al., 2012), while, high CO_2 concentration (equal or above 15%) results in stem and berry browning (Crisosto et al., 2002b; Retamales et al., 2003). Moreover, Modified Atmosphere Packaging (MAP) technique is considered as a non-toxic method for keeping quality of fruit and vegetables (Artés, 1976; Kader et al., 1989) and could be an alternative methods which control or avoid table grapes postharvest decay and maintains their visual and sensory quality (Artés-Hernández et al., 2004). The application of MAP can result in reduction of respiratory activity, retardation of softening and ripening and restraint of pathogens and reduced incidence of various physiological disorders (Caleb et al. 2013). MAP, as a semi-permeable coating with an adjusted ambience of CO_2/O_2 inside small storage environment, has been proven to prolong the storability of perishable commodities like grapes (Hagenmaier, 2005). Several authors consider MAP with 15% O_2 and 10% CO_2 such as a cheap and easy technique, which might be useful as an alternative to SO_2 (Crisosto et al., 2002b; Artés-Hernández et al., 2004).

However, these treatments vary in their effectiveness and lack enough support to replace SO_2 as a commercial practice. Few studies have evaluated their effects on common quality attributes as phenolic and aromatic compounds, in addition to decay control (Sanchez-Ballesta et al., 2006, 2007; Romero et al., 2009; Ustun et al., 2012). Therefore, in this study a detailed investigation was carried out to determine the effects of MAP combined with superficial disinfectant, as high concentrations of gaseous O_3 or CO_2, on decay incidence, sensorial quality maintainence, antioxidant capacity, total phenolic compounds, total and individual anthocyanins of organic Scarlotta® table grapes during cold storage (CS) period and after simulate commercial shelf life (SL).

2 Material and methods

2.1 Plant material

The experiment was undertaken in 2014 in an organic table grape vineyard located in Gioia del Colle (Southeast of Italy) under Mediterranean climate conditions. Four-year-old organic Scarlotta seedless® brand "Sugranineteen" table grapes grafted onto 140 Ruggeri (Vitis berlandieri × V. rupestris), with historic and current high incidence of gray mold. Vines were spaced 2 × 3.5 m (≈1428 vines/ha), trained to an overhead trellis system ('tendone') and covered with plastic film to protect grapes from rains and hailstorm, with drip irrigated.

Harvested clusters were transported to the laboratory and immediately precooled. The clusters were selected based on uniform berry size, color, firmness and freedom from evident defects or diseases. The selected clusters met European Union ("EU") Class 1 and in agreement with Sun World Quality Specifications. Selected bunches were at commercial maturity with sugar-acid ratio of 26:1; medium

133 symmetrical and well-filled bunches with a size of about 650 g; berries large, elongated
134 with diameter around 23 mm.
135 Selected grape clusters were randomly distributed into batches with five
136 replicates of one cluster per pretreatment. Clusters were placed inside plastic boxes
137 (carton Pack®) model CL1/135 (each box constituted a replicate) of 1 kg capacity.

138 ## 2.2 Pretreatments

139 Grape boxes were placed inside sealed barrels provided with two pipes
140 connected to gaz analyser, the first one for removing the air and the second to treat the
141 grapes as follows:

142 i) Gaseous O_3 concentration at 5, 10 and 20 µL L^{-1} mixed with air for 30 min;
143 gaseous O_3 was generated by OZAB-MF-A (Aeraque I.T. S.r.l., Stradella
144 (PV), Italy), and its concentration was monitored through OZOMAT-MP
145 (Anseros Ozone Gas Analyser MP, Germany);
146 ii) CO_2 concentration at 50 and 70% mixed with air for 24 h, the CO_2
147 concentation was monitored and adjusted throught SERVOPRO 1440 Gas
148 Analyser (SERVOMEX, USA).

149 The obtained results of all these pretreatments were compared to untreated grapes
150 (control). Except non-packed control, all the remaining grape boxes were packed in film
151 bags (85 µm thickness), made of polyamide (20 µm) / polyethylene (65 µm) (PA/PE),
152 under 2% O_2:5% CO_2:93% N_2 MAP, hermetically sealed using a heat sealer (MD,
153 Italy). Then, stored under simulated shipping conditions in container at 0±0.5 °C and
154 90-95% relative humidity (RH) for 55 days. At the end of storage, the temperature was
155 raised at 15±1.0 °C for one-week to simulate commercial shelf life (SL) as retail sale
156 period.

2.3 Measurement of table grapes respiration rates

Respiration rates were measured through apparent Michaëlis constant (Km_{appO2}) and maximal oxygen respiration rate (RR_{maxO2}) by using the closed system method (Lee, 1987; Haggar et al., 1992). Table grapes of known weight (≈ 270 g) were placed in a 1 L glass jar previously equilibrated in a temperature-controlled room. The initial gas composition inside each jar was set by gas flushing. Initial CO_2 partial pressure was constant and equal to atmospheric concentration 0.03% and initial O_2 partial pressures were 5, 10, and 20%. At periodic intervals, gases were sampled through a silicone septum set in the jar lid and analyzed using a CheckMateII O_2/CO_2 analyser (PBI Dansensor, Ringsted, Denmark). Experiments were stopped when the change in CO_2 partial pressures became greater than 1.5%. Each experiment was done in triplicate. The linear part of the Lineweaver plot ($1/RR_{O2}$ against $1/O_2$) was extrapolated to estimate the apparent Michaelis constant (Km_{appO2}) and the maximal oxygen respiration rate ($RR_{max\ O2}$).

2.4 Film permeability

Different pieces (130×125 mm) of previously mentioned film packaging PAPE (85 µm thickness) were sealed on two sides forming pouches, these pouches were flushed with 4% O_2: 15% CO_2: 81% N_2. During the sampling period, the pouches (three replicates) were stored at 20 °C and 40 % RH. During a storage period of 10 days, the changes in headspace gas composition were measured at interval times by using a CheckMateII O_2/CO_2 analyser (PBI Dansensor, Ringsted, Denmark). In addition, the O_2 and CO_2 permeation process through the packaging film, were calculated by derived Fick's law and the obtained result were expressed in mol m^{-1} s^{-1} Pa^{-1} (Larsen et al., 2000).

2.5 Modelling approach to simulate gas headspace composition

To predict gas atmosphere changes inside packaging during storage period, a mathematical model considering simultaneously gas diffusion through film packaging and grapes respiration rate, was developed and solved with Matlab® software (The Mathworks Inc, Natick, Mass., U.S.A).

Gas exchanges through the plastic film were represented by the classic permeability equation based on the 1st Fick's diffusion law for thin and infinite films (Crank and Park, 1968):

$$J = \frac{Pe \times S}{e} \times \Delta P$$

where **J** is the gas flux per time unit through the film (mol s^{-1}); **Pe** is the gas permeability coefficient of the film (mol m^{-1} s^{-1} Pa^{-1}); **S** is the surface area of film (m^2); **e** is the film thickness (m); and **ΔP** is the gas partial differential pressure between the outside and inside of the package (Pa).

Respiratory activity is described by a Michaëlis-Menten-type equation with a noncompetitive carbon dioxide inhibition (Lee et al., 1991; Fonseca et al., 2002):

$$RR_{O2} = \frac{RR_{maxO2} \times pO_2}{Km_{appO2} \times pO_2}$$

where $\mathbf{RR_{O2}}$ is the oxygen respiration rate (mmol kg^{-1} h^{-1}); $\mathbf{RR_{maxO2}}$ is the maximum oxygen respiration rate; $\mathbf{pO_2}$ is the gase partial pressures (kPa); $\mathbf{Km_{appO2}}$ is the apparent constant of Michaëlis-Menten equation (kPa) defined as the amount of sub-strate providing the reaction rate of $RR_{maxO2}/2$.

In addition, the temperature quotient (Q_{10}) was calculated from the slope of the regression line to obtain the temperature dependence of respiration. Q_{10} indicates the

increase in the respiration rate caused by a 10 °C increase in temperature. Q_{10} values were calculated using the following equation, where R2 and R1 are relative respiration rates at two temperatures, T2 and T1 (T2>T1).

$$Q_{10} = (R2/ R1)^{10/(T2 - T1)}$$

2.6 Decay incidence and weight loss

Decay incidence was measured in naturally infected Scarlotta® organic grapes after each sampling time (at harvest time, 15, 30 and 45 days) at 0 °C, and 55 days at 0 °C + SL. Decay incidence represented berries with visible "slip-skin" was calculated as the weight of the decayed berries after removal from the entire cluster. Moreover, cumulative decay incidence was expressed as a percentage of loss during all the storage period at 0 °C and after SL.

Concerning weight loss, its percentage was determined according to the following expression: $\%\ WL_t = (M_0 - M_t) \times 100 / M_0$, where $\%\ WL_t$ is the percentage mass loss at time t, M_0 is the initial sample mass and M_t is the sample mass at time t. The sample weight was determined by means of a digital precision balance (±0.01 g).

2.7 Mechanical attributes

Mechanical characteristics expressed in Newton (N), were measured using penetrometer (Digital Fruit firmness tester, TR Turoni, Italy). These attributes included; force needed to detach berries from the rachis (berry detachment force), maximum force necessary to puncture the skin of an individual berry with a 2 mm probe that penetrated to a depth of 6 mm (skin firmness), and then the force required to compress a berry through a flat cylinder probe of 8 mm diameter to reach a depth of 5 mm (berry firmness).

2.8 Chemical attributes

Regarding the chemical analysis, berries were filtered through plastic bag (BagPage®) fitted with filter to extract the juice. The Soluble Solid Content (SSC) was determined with digital refractometer (Atago, Japan) and total titratable acidity (TA) expressed in grams of tartaric acid per liter of table grape juice, was assessed by making a titration with 0.1 N NaOH up to pH 7, (OIV-MA-AS313-01, 2009). Finally, the juice pH was quantified by a pH-meter (Crison, Spain).

2.9 Color analysis

The berry skin color was measured through a spectrocolorimeter (Minolta CR 400 ChromaMeter, Japan), by assaying 50 berries for each replicate. Color parameters: L^* (lightness) corresponding to a black-white scale (0, black; 100, white), a^* (red tendency), b^* (yellow tendency) were recorded using the CIELAB color system. From these values, different indices were calculated:

- Hue angle ($h°$) [$\tan^{-1}$ b/a] which is the attribute of a visual sensation according to which an area appears to be similar to one of the perceived colors, red, yellow, green and blue, or a combination of two of them;
- Color index for red grapes (CIRG) as CIRG=[(180-$h°$) /(L^*+C^*)] based on the parameters L^*, a^*, b^*, and its characterized by showing a high correlation with the external visual color of the fruit (Carreño et al., 1995).

2.10 Rachis chlorophyll content

Rachis chlorophyll was extracted by immersing 0.5 g of fresh chopped rachides (grinded in cold liquid nitrogen) in 25 mL of pure methanol (99.9%) for 24 h at 4 °C in darkness. The quantification of chlorophyll was carried out by using a spectrophotometer (UV-1800, Shimadzu, Japan), then the samples were exposed to

250 visible light at a wavelength of (652.4, 665.2 and 470 nm; the content was expressed as
251 mg kg^{-1} fresh weight using Lichtenthaler's formula (Lichtenthaler, 1987).

252 **2.11 Extraction of phenolic compounds**

253 From each replicate, 10 berries were divided into two sub-samples (five
254 berries/each). The extraction of antioxidant compounds from berry skins of sub-samples
255 was carried out on the skins removed manually from the pulp, dried with filter paper
256 and then macerated in 20 mL of ethanol/water/HCl solution (70/30/1 v/v) overnight at
257 room temperature (Gambacorta et al., 2011). Finally, the extract was filtered through
258 filter paper and immediately submitted to analysis. The separated pulp was
259 homogenized in a blender, successively centrifuged at 15,000 g for 5 min and the clear
260 juice was immediately submitted to analysis.

261 **2.12 Analysis of antioxidant activity**

262 Antioxidant activity (AA) in skin and flesh was analyzed with the ABTS [2,2′-
263 azino-bis (3-ethylbenzothiazoline-6-sulfonic acid)] assay, this assay is based on free-
264 radical-scavenging activity. The results were expressed as mmol Trolox (6-hydroxy-2,
265 5, 7, 8-tetramethylchromane-2-carboxylic acid) equivalent antioxidant capacity (TEAC)
266 for kg^{-1} of skin or flesh. For the calibration process, Trolox standard solutions were
267 prepared at a concentration ranging from 10 to 800 μmol L^{-1}. Antioxidant activity was
268 measured in the ABTS assay through the ability of antioxidants to scavenge the ABTS
269 radical cation ($ABTS^{\bullet+}$, a blue/green chromophore) by inhibiting its absorption at 732
270 nm. The ABTS antioxidant test was performed according to the method reported by Re
271 *et al.* (1999) with slight modifications. In order to produce $ABTS^{\bullet+}$, 7 mmol L^{-1} ABTS
272 solution was reacted with 2.45 mmol L^{-1} potassium persulfate aqueous solution for 16 h
273 at room temperature and darkness conditions. The solution of $ABTS^{\bullet+}$ was then diluted

with ethanol to an absorbance of 0.90±0.03 at 732 nm; after the addition of either 100 µL of skin extract (diluted at 1:20 with ethanol) or undiluted pulp juice to 3.9 mL of diluted $ABTS^{\bullet+}$ solution, the absorbance was measured after 5 min (Ferrara et al., 2015).

2.13 Total phenolic content

Total phenols content was determined on grape fleshes and skins extract, the phenolic content was determined by Folin-Ciocalteu method using an UV-visible spectrophotometer (Beckman Coulter, USA). Sample solution of 100 µL of skin extracts (diluted at 1:25 with ethanol/water/HCl solution (70/30/1 v/v)) or undiluted pulp juice was added to 500 µL of H_2O and then to 100 µL of Folin-Ciocalteu's reagent; homogenized and incubated at room temperature for 5 min, after 500 µL of 10% of sodium carbonate was added, the mixture was then incubated for 90 min at room temperature, following this incubation period, the absorbance was measured at 700 nm. Total phenolic content was calculated on the basis of a calibration curve of gallic acid and expressed as mg gallic acid equivalent (GAE) kg^{-1} of fresh weight. The standard calibration curve was performed from 0.08 to 0.002 mg mL^{-1} of gallic acid pure standard (Sigma Aldrich).

2.14 Anthocyanins analysis

Anthocyanin composition was determined on grape skins extract, by using a Waters 600 E HPLC, (Waters Inc.), which included a quaternary pump, a PDA and an injection valve with a 20 µL loop. Sample extracts, previously filtered on a 0.45 µm nylon membrane, were injected into a NovaPack C18 (150 × 3.9 mm, 4 µm particle size, Waters Inc.) column maintained at 30 °C and eluted at a flow rate of 1 mL min^{-1} with 10% formic acid (solvent A), and acetonitrile (solvent B). The gradient program for solvent A was 0-1 min 95%, 1-22 min 60%, 22-27 min 30%, 27-35 min 30%. The

eluates were monitored at 520 nm, and quantitative analysis was made according to the external standard method with a calibration curve obtained by injection of solutions at different concentration of malvidin-3-glucoside (Sigma Aldrich) (R^2 = 0.9991). Tentative identification of anthocyanins was achieved by combining the elution pattern and data reported in literature (Revilla and Ryan, 2000; Singh Brar et al., 2008; Acevado De la Cruz et al., 2012); the results were expressed as mg kg^{-1} malvidin-3-glucoside equivalents.

Total anthocyanin content was determined using diluted skin extract 1:100 with ethanol/water/HCl solution (70/30/1 v/v) in agreement with the method reported by Gambacorta et al. (2011). The obtained results were expressed as mg kg^{-1} Malvidin-3-glucoside.

2.15 Extraction and analysis of acetaldehyde and ethanol by SPME-GC/MS

The extraction of volatile compounds (mainly used for acetaldehyde and ethanol compounds) was carried out by headspace solid phase micro-extraction (SPME) using a triphasic fibres DVB/Carboxen/PDMS 50/30 μm.

Frozen grapes were pounded in a mortar until obtaining a homogeneous compound. For each measurement, fibre was exposed to the headspace of a 12 mL screw-capped vial, which contained 2 g of puree with 2 mL of 0.1 mol phosphor-citrate buffer pH 5, 100 μL of pectolytic enzymes for oenological use Endozym (diluted 1000 times in water), and 30 μL of internal standard solution (3-pentanone). The extraction was performed for 30 min at 50±1 °C with an equilibration time of 5 min. All used fibres were conditioned by keeping them in the GC injector following instructions from manufacturer. After the extraction step, fibres were desorbed in a split/splitless injector at 220 °C, for 1.5 min split ratio was 1:20. Gas chromatography/mass spectrometry (GC/MS) analysis was

performed on a Thermo Scientific ISQ™ QD Single Quadrupole GC-MS System. Compounds were separated on a WAX MS capillary column (20 m × 0.1 mm i.d.; 0.1 μm film thickness), by applying the following temperature program: 50 °C for 0.1 min, 50-180 °C at 13 °C min^{-1}, 180 - 220 °C at 18 °C min^{-1}. Mass detector conditions were electronic impact mode at 70 eV, source temperature 250 °C and mass scanning acquisition range: 34 - 200 Da. Carrier gas was helium with a constant flowat 0.4 mL min^{-1}.

Chromatographic data were analyzed with Xcalibur v2.0 program; moreover, the identification of acetaldehyde and ethanol components was based on comparison of their GC retention times and mass spectra with reference spectra contained in a library (National Institute of Standards and Technology NIST) of reference data (matching score P>80). Both components were expressed in relative quantities as 3-pentanone equivalent; moreover, acetaldehyde was quantified as μg kg^{-1} and ethanol as mg kg^{-1} fresh weight.

2.16 Sensory quality

Clusters were evaluated by six untrained panelists and individually scored: sourness, aroma, stem and berry browning and stem dehydration, using the following five-point intensity scale of damage (1: none; 2: slight; 3: moderate and limit of marketability; 4: severe; 5: extreme). Visual appearance, flavor, juiciness, sweetness and crunchiness of berries were evaluated on a nine-point subjective scale (1: bad; 3: fair; 5: moderate and limit of marketability; 7: good; 9: excellent) (Artés-Hernández et al., 2004).

2.17 Statistical analysis

Data mean values have been separated analysing the data through the Matlab software, the Tukey's honestly significant difference (HSD) post-hoc test has been used with a familywise error rate (FWER) set to 0.05 significance level.

Decay incidence data were transformed (arcsin of the square root of the proportion of affected fruit) before the analysis.

3 Results and discussion

3.1 Film permeability

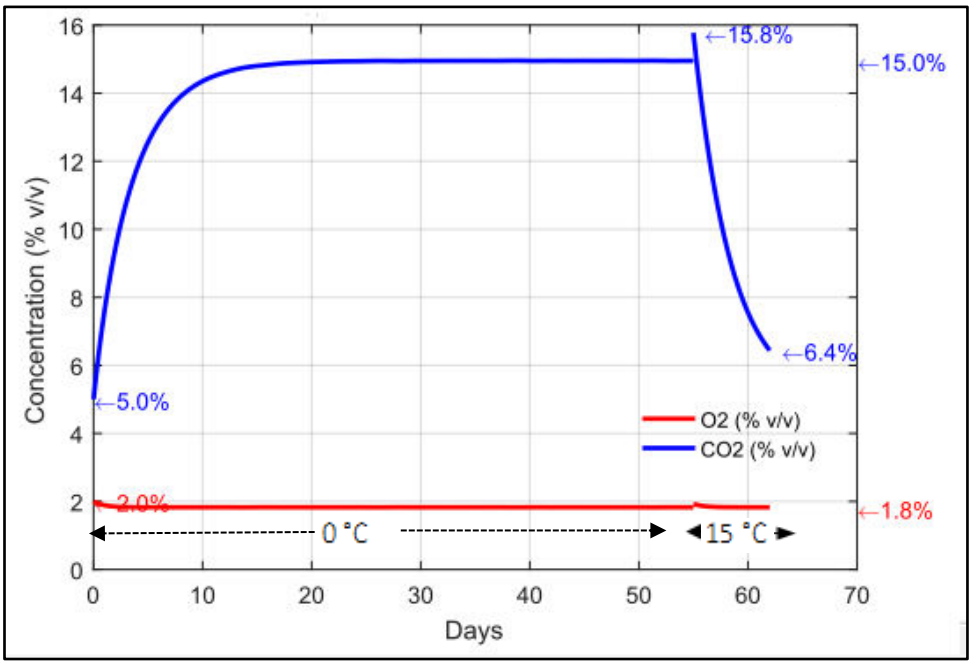
According to Lamikanra (2002), the commercial used film packaging PAPE showed a low permeability against O_2 and CO_2 transmission rate (7.01×10^{-16} and $1.98\text{-}\times 10^{-15}$ mol m^{-1} s^{-1} Pa^{-1}, respectively).

3.2 Respiration rate

Apparent Michaelis-Menten parameters of table grapes were estimated from respiratory activity in the closed system, which allowed the RR_{O2} determination through the oxygen depletion. Then, the RR_{maxO2} and the Km_{appO2} were estimated on the Lineweaver plot. The RR_{maxO2} and the Km_{appO2} of table grapes were 1.90 mmol h^{-1} kg^{-1} and 34.63 kPa respectively, demonstrating low physiological activity of table grapes. Furthermore, the effect of temperature on respiration in fresh fruits and vegetables is very significant (Cameron et al., 1994). A wide variety of enzymatic reactions are involved in respiration. The rate of all of these reactions increases exponentially with increasing temperature within the physiological temperature range (Exama et al., 1993). The mathematical description of respiration increases (Q_{10}) of table grapes was around 2.12 such as main of fruits and vegetables.

3.3 Predicted headspace O_2 and CO_2 concentration

Fruit and vegetables consume oxygen and produce carbon dioxide while packed, giving rise to a modification of the headspace gas composition (Jayas and Jeyamkondan, 2002). The respiration of the packed product and the gas permeability of the film influence the change in gaseous composition of the environment surrounding the product. As expected during cold storage, MAP was able to increase significantly CO_2 percentage with a tight decrease in O_2 concentrations in the surrounding of grapes bunches. The gas equilibrium was reached after around 16 days for CO_2 and 3 days for O_2 (15% and 1.8%, respectively) at 0 °C of storage (Figure 1). Howerver during simulated commercial shipping at 15 °C for one week, a fast increase in CO_2 and O_2 concentrations were recorded after one day reaching 15.8% and 2%, respectively, due to the suddenly increase of temperature. The registred increase was followed by a severe decrease in CO_2 concentration reaching 6.4% at the end of storage, while, O_2 concentration returned to the initial equilibrium (1.8%). Thus suggesting that headspace gas condition in the package was affected by the increasing temperature, wich had an impact on grapes respiration rate and film barrier properties.



385 **Figure 1.** Predicted evolution over storage of O_2 and CO_2 concentrations in the PAPE
386 bag headspace samples packed under active MAP.
387

388 ### 3.4 Weight loss

389 The weight loss increased significantly in all samples as the storage time
390 increased; whereas, the effect of pretreatments were not significant at different sampling
391 time (Table 1). In all samples included packed control, the weight loss reached values
392 less than 1% after 45 days of cold storage and slightly higher than 1% after simulated
393 commercial shelf life (SL). However, in non-packed control weight loss reached 1.4%
394 after 15 days of cold storage (data not shown). These data confirmed the previous
395 reports on the effects of MAP and water permeation properties of the used film
396 regarding the preservation of table grapes moisture (Artés-Hernández et al., 2007,
397 Ngcobo et al., 2012).

Table 1. Effects of pretreatments and MAP on weight loss and decay incidence of organic table grapes cv. Scarlotta® during cold storage and after simulated commercial shelf life.

	Weight loss (%)				**Decay incidence** (%)			
Treatment	**15d**	**30d**	**45d**	**55d+SL**	**15d**	**30d**	**45d**	**55d+SL**
Control-MAP	0,68a	0,65a	0.75b	1.19ab	0,02a	2,04a	2.51a	1.20b
O_3-5 µL L^{-1}	0,47bc	0,54a	0.69bc	1.27a	0,55a	0,97ab	1.05ab	0.89b
O_3-10 µL L^{-1}	0,51bc	0,56a	0.70bc	1.20ab	0,00a	0,02b	2.61a	2.90a
O_3-20 µL L^{-1}	0,45c	0,60a	0.67c	1.20ab	0,00a	0,98ab	0.85b	0.06c
CO_2-50%	0,58b	0,63a	0.80ab	1.02b	0,00a	0,09b	1.03ab	0.00c
CO_2-70%	0,53bc	0,63a	0.84a	1.11ab	0,29a	0,58ab	0.45b	0.00c

Incidence data were transformed (arcsin of the square root of the proportion of affected fruit) before statistical analysis. Values presented are non-transformed means. Values followed by the same letter for each assessement time did not differ significantly according to HSD post-hoc test with FWER≤0.05.

Table 2. Effects of pretreatments and MAP on physical and chemical qualities of organic table grapes cv. Scarlotta® after cold storage and simulated commercial shelf life.

	Physical qualities						**Chemical qualities**					
Harvest time	**Berry detachment force 2.82 N**		**Berry firmness 11.83 N**		**Skin firmness 2.32 N**		**pH 3.23**		**SSC 15.34 %**		**TA 5.89 g tartaric acid L^{-1}**	
Treatment	**45d**	**55d+SL**	**45d**	**55d+SL**	**45d**	**55d+SL**	**45d**	**55d+SL**	**45d**	**55d+SL**	**45d**	**55d+SL**
Control-MAP	2.37a	2.31a	8.49ab	10.23ab	1.57ab	1.56ab	3.22a	3.29ab	15.32ab	14.75ab	5.99ab	5.44a
O_3-5 µL L^{-1}	2.35a	2.15a	7.92b	9.26ab	1.19c	1.13c	3.22a	3.17c	14.94ab	13.40bc	6.26ab	5.52a
O_3-10 µL L^{-1}	2.46a	1.99a	9.45a	10.50a	1.71a	1.55ab	3.22a	3.18c	15.53ab	15.54a	5.39bc	5.46a
O_3-20 µL L^{-1}	2.18a	2.23a	7.88b	9.13b	1.71a	1.91a	3.25a	3.35a	15.95a	14.94a	6.53a	5.19a
CO_2-50%	2.31a	1.99a	9.05ab	10.32ab	1.39bc	1.48bc	3.28a	3.24ab	14.48b	14.70ab	5.58bc	5.16a
CO_2-70%	2.49a	2.21a	8.56ab	10.41ab	1.42ab	1.11c	3.27a	3.22bc	16.13a	13.14c	5.20c	5.21a

Mean values followed by the same letter for each assessement time did not differ significantly according to HSD post-hoc test with FWER≤0.05.

Table 3. Effects of pretreatments and MAP on color parameters of organic table grapes cv. Scarlotta® after cold storage and simulated commercial shelf life.

Harvest time	*L** 38.71		*h*° 1.98		CIRG 4.24	
Treatment	**45d**	**55d+SL**	**45d**	**55d+SL**	**45d**	**55d+SL**
Control-MAP	40.10a	38.65b	11.83a	17.72b	3.55c	3.58bc
O_3-5 µL L^{-1}	40.70a	36.49c	-5.45bc	38.11a	3.97b	3.41bc
O_3-10 µL L^{-1}	39.25a	38.90ab	-0.75ac	25.48ab	3.94bc	3.49bc
O_3-20 µL L^{-1}	38.88a	36.80c	-12.24c	12.79b	4.43a	4.05a
CO_2-50%	40.44a	38.89ab	4.48ab	20.44ab	3.88bc	3.69b
CO_2-70%	41.51a	39.89a	5.27ac	35.41a	3.84bc	3.22c

Mean values followed by the same letter for each assessement time did not differ significantly according to HSD post-hoc test with FWER≤0.05.

Table 4. Effects of pretreatments and MAP on antioxidant activity, total phenolic compounds and total anthocyanins of organic table grapes cv. Scarlotta® stored at 0°C.

	Antioxidant activity (mmol kg^{-1})						Total phenolic content (mg GAE kg^{-1})						Total anthocyanins (mg Malvidin-3-glucoside kg^{-1}) 110.89		
Harvest time	**Skin 78.32**			**Flesh 14.05**			**Skin 451.45**			**Flesh 141.97**					
Treatment	**15d**	**30d**	**45d**	**15d**	**30d**	**45d**	**15d**	**30d**	**45d**	**15d**	**30d**	**45d**	**15d**	**30d**	**45d**
Control-MAP	75.44a	79.63a	78.18a	14.67b	14.63b	15.96ab	447.99ab	576.48a	417.05c	169.77ab	164.49ab	199.39a	103.38b	124.07ab	75.06c
O_3-5 µL L^{-1}	53.60b	72.57ab	80.69a	15.02b	15.68ab	19.39a	434.88ac	418.32bd	422.25bc	166.10ab	193.35a	190.32a	106.03ab	127.42a	119.54a
O_3-10 µL L^{-1}	69.03ab	75.28a	77.41a	12.08c	10.35c	17.31ac	399.81bc	451.48ad	563.93a	119.84b	139.69b	186.13a	112.84a	114.80c	116.59a
O_3-20 µL L^{-1}	73.87a	84.2a	77.01a	14.58b	14.74b	17.94a	420.59ac	522.85abc	499.21ab	162.39ab	13565b	187.88a	110.68ab	119.89b	125.49a
CO_2-50%	79.72a	86.24a	60.34b	18.94a	16.60a	13.83b	487.67a	411.05cd	377.49c	215.50a	160.96ab	171.53a	107.60ab	69.95d	62.57d
CO_2-70%	56.16b	57.64b	82.11a	11 .62c	10.06c	14.80bc	372.42c	376.96d	535.79a	188.08a	170.37ab	156.08a	67.14c	67.90d	100.82b

Mean values followed by the same letter for each assessement time did not differ significantly according to HSD post-hoc test with FWER≤0.05.

Table 5. Effects of pretreatments and MAP on the concentration of individual anthocyanins of organic table grapes cv. Scarlotta® stored at 0°C.

Harvest time	Dp 0.96 mg kg^{-1}			Cy 9.87 mg kg^{-1}			Pt 1.56 mg kg^{-1}			Pn 24.66 mg kg^{-1}			Mv 11.62 mg kg^{-1}			Ac-A 17.12 mg kg^{-1}		
Treatment	**15d**	**30d**	**45d**	**15d**	**30d**	**45d**	**15d**	**30d**	**45d**	**15d**	**30d**	**45d**	**15d**	**30d**	**45d**	**15d**	**30d**	**45d**
Control-MAP	1.15a	1.34a	0.64a	7.85ab	5.83ac	10.44a	1.23a	1.90a	0.55a	20.54b	45.46a	24.15ab	13.64a	15.67a	5.53a	19.33a	21.55a	7.53b
O_3-5 µL L^{-1}	0.88a	0.80ab	0.65a	10.57ab	12.87b	6.93ab	0.33b	0.89a	1.30a	12.18c	35.93ab	29.93ab	9.14a	6.66b	12.90a	12.91a	11.70b	18.33ab
O_3-10 µL L^{-1}	0.80a	0.63ab	0.43a	9.68ab	9.50ab	7.72ab	0.62ab	0.77a	0.84a	23.08b	25.45bc	28.34ab	8.88a	6.14b	8.04a	14.35a	11.57b	17.24ab
O_3-20 µL L^{-1}	0.70a	1.23ab	1.05a	10.69a	4.88ad	8.44ab	0.81ab	0.69a	1.58a	34.91a	20.85c	38.66a	6.39a	6.62b	11.60a	12.05a	10.18b	24.27a
CO_2-50%	0.64a	0.46ab	0.47a	4.74bc	4.38cd	6.08ab	1.05ab	0.66a	0.59a	34.40a	18.58c	14.74b	11.33a	5.28b	6.47a	17.12a	11.62b	12.81ab
CO_2-70%	0.47a	0.54ab	0.25b	1.08c	0.98d	4.44b	1.27a	0.98a	1.70a	21.54b	15.41c	25.28ab	12.52a	13.42a	14.76a	19.20a	21.28a	16.70ab

Dp, delphinidin-3-glucoside; Cy, cyanidin3-glucoside; Pt, petunidin-3-glucoside; Pn, peonidin-3-glucoside; Mv, malvidin-3-glucoside, Ac-A, acylated

Mean values followed by the same letter for each assessement time did not differ significantly according to HSD post-hoc test with FWER≤0.05.

3.5 Decay incidence

The effects of pretreatments and storage time were investigated in naturally infected clusters of organic table grapes cv. Scarlotta® (Table 1), where natural incidence of decay was mostly caused by *B. cinerea.* The relative observations did not show any significant differences between packed untreated and pretreated samples until 15 days of cold storage with decay incidence around 0 to 0.55%, at the opposite in non-packed control the decay attained 27% (data not shown). Consequently, the non-packed control samples were excluded from the trial after the first sampling time (15 days of CS). Moreover, the situation was worsening after 30 days of CS, where the packed control grapes reached 2.04% of decay; however, the remaining pretreated grapes showed less than 1% decay. After 45 days of CS, pretreated samples with O_3 at 20 µL L^{-1} and CO_2 at 70% maintained significant high control of decay (less than 1% decay) compared to packed control (2.51%) and a remaining pretreatments. Furthermore, after 55 days of CS + SL, trend of decay incidence decreased in samples pretreated with O_3 at 20 µL L^{-1} and CO_2 reaching values around 0% decay compared to packed control samples with 1.2% of decay. Cumulative decay incidence confirmed also the efficiency of these pretreatments (Figure 2); to control the decay after 45 days of CS and 55 days CS + SL by reducing it 5 to 6 fold compared to packed control.

The effect of pretreatment with O_3 or CO_2 at high concentration to control berries decay, was confirmed in previous work in which the decay decreased through direct action against *B. cinerea*, including partial inhibition of conidia germination (Mlikota Gabler et al., 2010, Karaca et al., 2012, Teles et al., 2014). The efficiency of these gases in controlling decay could be due to the internal increase of ethanol

and acetaldehyde to fungal-toxic concentrations (Pesis, 2005) or the formation of reactive oxygen species associated with stilbene synthase gene expression and resveratrol accumulation (Sanchez-Ballesta et al., 2006; Romero et al., 2008; Minas et al., 2010).

According to current E.U. marketing regulations EC N° 543/2011, the maximum decay rate accepted is 1% by weight of table grapes bunches at the receiving point for Class I EU grapes. During all storage period (CS and SL), all samples packed under MAP, controlled decay incidence below this accepted maximum rate (1%); moreover, samples pretreated with O_3 at 20 µL L^{-1} and CO_2 at 50%, yielded cumulative decay incidence within this limit after CS and SL, by reaching the minimal quality standards for commercial table grapes.

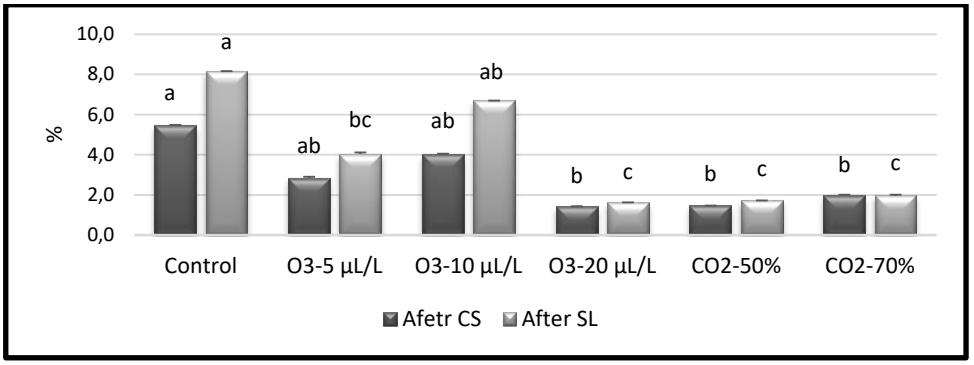


Figure 2. Effects of pretreatments and MAP on cumulative incidence of organic table grapes cv. Scarlotta® after cold storage (CS) and shelf life (SL).
Cumulative incidence data were transformed (arcsin of the square root of the proportion of affected fruit) before statistical analysis. Values presented are non-transformed means. Values followed by the same letter for each assessement time did not differ significantly according to HSD post-hoc test with FWER≤0.05.

3.6 Physical and chemical qualities

During the 45 days of cold storage, no significant differences of physical and chemical quality parameters were obtained between pretreated samples and control on organic table grapes cv. Scarlotta® at different sampling time. However, after simulated commercial shelf life (Table 2), some significant differences were observed, such the decreases of skin firmness, in samples pretreated with CO_2 at 70%

(0.11 N) and O_3 at 5 µL L^{-1} (0.12 N) compared to control (0.16 N). Likewise, pH and SSC in samples pretreated with O_3 at 5 - 10 µL L^{-1} (pH: 3.17 and 3.18, respectively) and CO_2 at 70% (pH: 3.22 and SSC: 3.14%) compared to control (pH: 3.29 and SSC: 14.75). These registered variations remained very tiny and no relevant. Similar results for changes in physical and chemical attributes were reported in "Red globe" grapes stored at 0 °C under several controlled atmospheres for up to 3 months weeks (Crisosto et al., 2002a), in "Superior seedless" grapes stored under different MAP and after 7 days CS + SL (Artés-Hernández et al., 2006), and in "Flame Seedless" grapes pretreated with 40% CO_2 and conserved under controlled atmosphere (Teles et al., 2014).

3.7 Berry color

The obtained results showed that most pretreatments retained the L^* and $h°$ of berries over all sampling times with no relevant changes; however, after SL, L^* decreased significantly regardless of pretreatments and the lower values were noted in samples pretreated with O_3 at 5 and 20 µL L^{-1} (36.49 and 36.8, respectively) compared to control (38.65) (Table 3). In addition, $h°$ increased significantly in almost all samples except samples pretreated with O_3 at 20 µL L^{-1} and packed control (12.79 and 17.72) compared to value at harvest (1.98). These similar results were already mentioned in unwrapped "Flame seedless" grapes after 18 days of CS (Martínez-Romero et al., 2003), in organic "Crimson" grapes after 30 days of CS immersed in hot ethanol (Mlikota Gabler et al., 2005), in "Red globe" grapes packed in MAP bags during three months of CS (Candir et al., 2012). According to Mlikota Gabler et al. (2005), the increases in $h◦$ and decrease in L^* values indicate a

progression in berry color toward brown, but the darker or deeper red color that they reported are not visible to the naked eye.

In addition, CIRG permitted the objective definition of the external color in all samples, based on this index, after SL only samples pretreated with O_3 at 20 µL L^{-1} (4.05) maintained red skin color compared to the harvest time (4.24). Furthermore, following the criterion of Carreno et al. (1996), the remaining samples presented pink skin color with values ranging between 3.22 and 3.69.

3.8 Rachis chlorophyll content

Rachis browning is considered the second most important postharvest problem of table grapes after decay control, moreover for the consumer, a green rachis is an indication of freshness, and hence, a brown rachis can be a major cause of consumer rejection and eventually fruit waste (Lichter, 2016).

Compared to harvest values (188.09 mg kg^{-1}), trend of rachis chlorophyll content decreased significantly during storage period, principally after 45 days of cold storage where samples pretreated with CO_2 at 50 and 70% presented very low concentration of chlorophyll (59.45 and 80.48 mg kg^{-1}, respectively) (Figure 3), while, rachis green color was maintained in samples pretreated with O_3 at 20 µL L^{-1} (139.89 mg kg^{-1}) followed by packed untreated samples (119.08 mg kg^{-1}) . However, only samples pretreated with O_3 at 20 µL L^{-1}maintained chlorophyll content during the whole period of CS. The obtained results concerning rachis chlorophyll content confirmed the subjective results obtained by the panelist for rachis browning after 45 days of CS.

The green color loss or rachis browning affects overall cluster quality and has been associated mainly to water loss (Valverde et al., 2005; Lichter et al., 2011) and

535 oxidation processes (Carvajal-Millán et al., 2001). However, several studies
536 suggested that other factors could be involved in rachis green color loss due to green
537 pigments degradation during the chlorophyll breakdown pathway and the consequent
538 formation of pheophytin-a by the putative enzyme Metal Chelating Substance (MCS)
539 (Shioi et al., 1996; Suzuki et al., 2005). Moreover, Hörtensteiner and Kräutler (2011)
540 reported that a non-enzymatic or a species-specific reaction generates a series of non-
541 colored catabolites that accumulates inside vacuole. Alternatively, results of the work
542 carried out by Carvajal-Millán et al. (2001) showed that clusters with severe rachis
543 browning symptoms had higher polyphenol oxidase (PPO) activity than clusters with
544 less rachis browning symptoms in "Flame Seedless" grapes. Additionally, Balic et al.
545 (2012) described a list of 30 senescence associative genes (SAGs). Suggesting that in
546 rachis of "Red Globe" grapes stored at 0 °C for 90 days, 10 genes increased the level
547 of transcript abundance, while another 7 did not show significant differences as
548 compared with harvest. Additionally, Silva-Sanzana et al. (2016) observed through
549 histological analysis of rachis that MAP storage increases rachis postharvest quality
550 of "Red Globe" grapes by reducing green color loss reported due to a combination of
551 processes involving a delay of green pigments degradation and a less accumulation
552 of brown compounds at the periderm and cortex tissues, thus preventing green
553 pigments masking.

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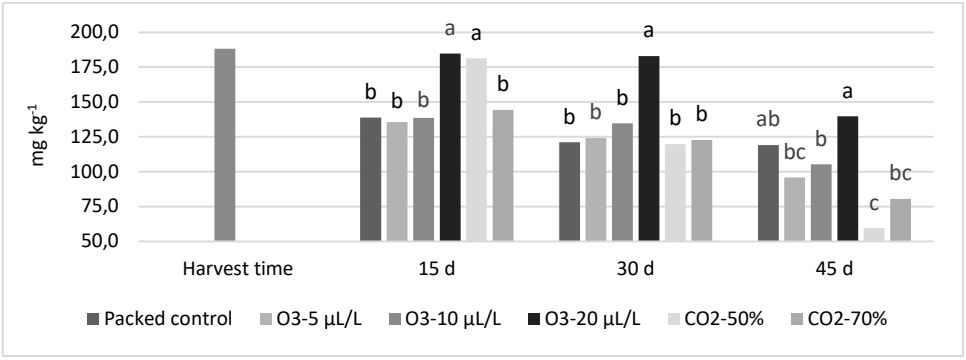

Figure. 3. Effects of pretreatments and MAP on rachis chlorophyll content of organic table grapes cv. Scarlotta® during cold storage.
Values followed by the same letter for each assessement time did not differ significantly according to HSD post-hoc test with FWER≤0.05.

3.9 Antioxidant activity and phenolic compounds

As expected, at harvest AA and total phenolic content in skin extract were respectively more than 5 and 3 fold higher than those in flesh (Table 4) in accordance with Pastrana-Bonilla et al. (2003).

Samples pretreated and untreated did not show the same trend for AA, total phenolic content and total anthocyanins. During CS, AA in flesh berries increased in all samples untreated and pretreated with O_3; this activity in skin berries was almost maintained in all samples; while, in samples pretreated with CO_2 at 50%, AA increased significantly in flesh and skin berries reaching high values after 15 and 30 days respectively, and decreased drastically at the end of storage. Regarding samples pretreated with CO_2 at 70%, AA decreased significantly after 15 and 30 days of cold storage and remained similar to those achieved in freshly harvested grapes. Sanchez-Ballestra et al. (2007) and Romero et al. (2008) reported the same results in "Cardinal" grapes treated with CO_2. The same observation was noted also regarding the total phenol content, where the trend in flesh berries increased significantly in all conserved samples, while in skin berries its concentration was maintained until the end of storage in almost all samples, exception of those pretreated with CO_2. In

580 previous work it was demonstrated that the antioxidant capacity is dependent on the
581 level and type of phenolic compounds (Lutz et al., 2011).

582 Concerning the development of total anthocyanins in skin berries, the results
583 showed two distinguished trends. In samples pretreated with O_3 the concentration of
584 anthocyanins increased significantly, which was paralleled by an increase in
585 antioxidant activity during cold storage (Table 4), this correlation was also observed
586 in "Cardinal" grapes after 12 days of cold storage (Sanchez-Ballesta et al., 2007).
587 Which could be explained by the fact that O_3 reacted as elicitors for the biosynthesis
588 of phenolic compounds (Vincente et al., 2014).

589 However, total anthocyanin decreased significantly in samples pretreated with
590 CO_2 during storage period to reach values of 100.82 and 62.57 mg Malvidin-3-
591 glucoside kg^{-1} in samples pretreated with CO_2 at 70% and 50%, respectivelly. The
592 results obtained are in agreement with those of Artés-Hernandez et al. (2003) which
593 observed a decrease in total anthocyanin content in "Napoleon" grapes when using
594 an atmosphere of 15% CO_2 and 5% O_2. Even if, it is already known that anthocyanin
595 synthesis continues after harvest and also during long-term cold storage by activating
596 phenylpropanoid gene expression, total anthocyanin accumulation and antioxidant
597 activity, whereas the application of CO_2 treatment reduces/inhibits these responses
598 (Sanchez-Ballesta et al., 2007, Romero et al., 2008).

599 **3.10 Anthocyanins content**

600 The anthocyanin profile consisted of twelve compounds (seven of them
601 acylated), with the prevalence of peonidin (Pn) forms (Figure 4) in agreement with
602 what was reported by Cantos et al. (2002); Sanchez-Ballesta et al. (2007) and Ferrara
603 et al. (2015). The most abundant anthocyanin present was peonidin-3-glucoside

(37%), followed by malvidin-3-glucoside (18%), cyanidin-3-glucoside (15%), and in lower quantities than other anthocyanins: petunidin-3-glucoside (2%) and delphinidin-3-glucoside (1%) (Table 5). According to Liang et al. (2011), the most abundant anthocyanin present in pink and red-colored cultivars was Pn forms, whereas cyanidin, malvidin and petunidin forms were abundant in red-black cultivars. This suggests that different proportions of individual anthocyanin compounds, in addition to their absolute amount, can affect the skin color of grapes (Ferrara et al., 2015). This result was confirmed at the end of cold storage where pretreatment with O_3 at 20 µL L^{-1} presented the highest concentration of Pn (38.66 mg kg^{-1}) and CIRG (4.43).

The individual anthocyanins in almost all samples showed not significant variation during storage period, and their values remained similar to those achieved in freshly harvested grapes. Except for cyanidin and delphinidin, where their concentrations decreased significantly in samples pretreated with CO_2 at 70%. Moreover, peonidin and acylated anthocyanins showed a similar trend with total anthocyanin content in samples pretreated with O_3 at 20 µL L^{-1}.

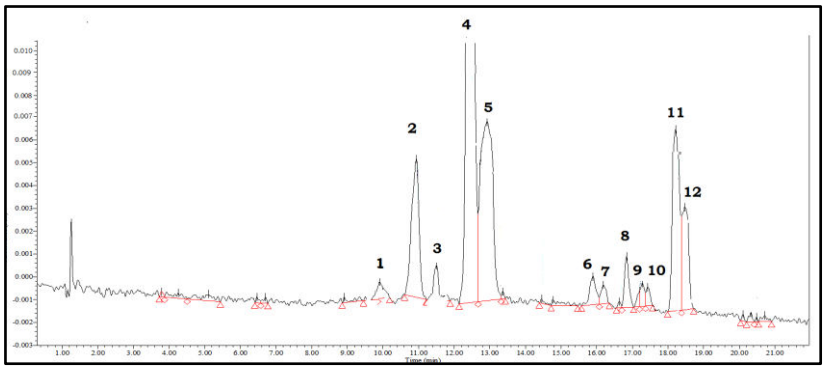

Figure 4. Anthocyanin profile of a skin extract of berries at harvest from organic table grapes cv. Scarlotta® berries [peaks: 1 = delphinidin-3-glucoside; 2 = cyanidin3-glucoside, 3 = petunidin-3-glucoside, 4 = peonidin-3-glucoside; 5 = malvidin-3glucoside; 6–12 = acylated anthocyanins].

626 **3.11 Acetaldehyde and ethanol**

627 During sampling time, almost all samples presented similar chromatogram
628 profile with the same volatile compounds. The chromatogram of total volatile
629 compounds showed that during storage period, several aromatic peaks disappeared
630 and new peaks became more visible like ethanol or appeared as Acetaldehyde. The
631 presence of these compounds in table grapes are mainly associated with fermentative
632 and biochemical changes induced by progressive maturation, which could induce
633 perceived off-flavor (Candir et al., 2012, Teles et al., 2014, Piazzolla et al., 2015).

634 Compared to the acetaldehyde and ethanol values at harvest (0 µg kg^{-1} and
635 0.08 mg kg^{-1}, respectively), trend of both components increased significantly during
636 storage period in all samples (Figure 5). Several not significant variation of
637 acetaldehyde and ethanol compounds were observed during conservation between
638 samples at different sampling time ($P<0.01$). Except at the end of cold storage, where
639 samples pretreated with O_3 at 20 and 10 µL L^{-1} present significant low values of
640 acetaldehyde (24.59 and 32.51 µg kg^{-1}) compared to packed untreated samples
641 (41.16 µg kg^{-1}). In addition, samples pretreated with O_3 at 20 µL L^{-1} presented
642 perceived low trend of acetaldehyde paralleled with trend of remaining samples.
643 Samples pretreated with CO_2 and packed untreated presented high concentration of
644 acetaldehyde during period of storage, similar result was also obtained by Teles et al.
645 (2014) on organic "Flame Seedless" grapes pre-stored with CO_2 at 40% for 24 - 48 h
646 and conserved for four weeks. According to Candir et al. (2012), a low concentration
647 of O_2 induces anaerobic respiration, which leads to undesirable metabolic reactions,
648 such as tissue breakdown and accumulation of acetaldehyde and ethanol in the tissue,
649 resulting in off-odors and off-flavors. The results concerning acetaldehyde and

ethanol content in berries at the end of cold storage confirmed the subjective results obtained by the panelist for the perceiving off-flavor after 45 days of CS.

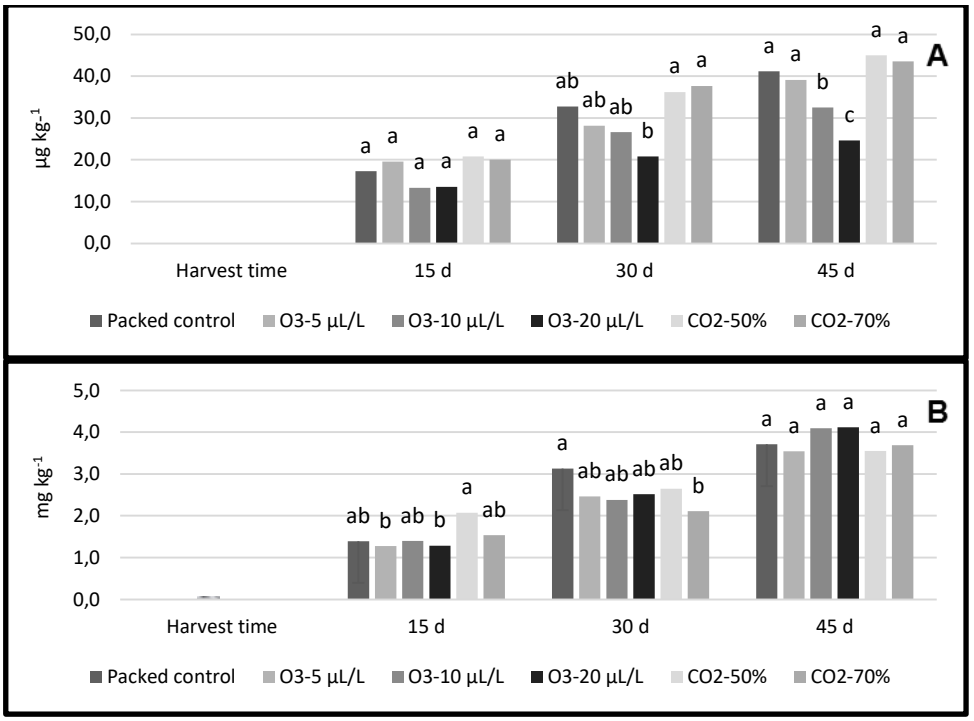

Figure 5. Effects of pretreatments and MAP on acetaldehyde (A) and ethanol (B) content on organic table grapes cv. Scarlotta® during cold storage.
Values followed by the same letter for each assessement time did not differ significantly according to HSD post-hoc test with FWER≤0.05

3.12 Sensory quality

After 45 days of cold storage, clusters pretreated with O_3 maintained good visual appearance compared to the control and good aroma was mainly conserved by untreated and treated samples with O_3 at 20 µL L^{-1}, while it decreased drastically in clusters pretreated with CO_2 at 50 and 70% (Figure 6). The same results were obtained after SL, except for good aroma, where also, samples pretreated with O_3 at 5 and 10 µL L^{-1} presented fair score. Furthermore, as described after 45 days of CS regarding juiciness and firmness of berries, also after SL almost all samples preserved juiciness of berries, for firmness untreated paked samples and pretreated with O_3 at 20 µL L^{-1} were at limit of marketability while in remaining samples, it was

669 judged as fair. Concerning sweetness after SL; packed control and pretreated samples
670 with O_3 at 20 and 10 µL L^{-1} obtained limit of marketability score, while in remaining
671 samples was refereed as very fair (Figure 6).

672 Equally, samples at both sampling time presented sourness in the taste, which
673 was considered as fair in almost all samples after 45 days of CS and fair in packed
674 control and pretreated samples with O_3 at 20 µL L^{-1}. Although after SL, in practically
675 all samples the score increased to reach limit marketable score and was perceived as
676 severe in samples pretreated with O_3 at 5 µL L^{-1} and CO_2 at 70%. Moreover after SL,
677 the panelist detected severe off-flavor in berries pretreated with O_3 at 5 µL L^{-1} and
678 CO_2 at 70%, limit of marketability in samples pretreated with O_3 at 10 µL L^{-1} and
679 CO_2 at 50%, and fair in packed control and pretreated samples with O_3 at 20 µL L^{-1}.
680 The observed off-flavors could be due to an accumulation of fermentative volatiles
681 compounds in berries like ethanol and acetaldehyde (Candir et al., 2012; Teles et al.,
682 2014). Consequently, gas composition inside package did not influence grapes flavor;
683 our data confirm results obtained by Artés-Hernández et al., (2006) in "Superior
684 Seedless" grapes stored under MAP. Regarding rachis browning attribute, SL
685 increased the perceptibility of rachis browning to limit of marketability especially in
686 packed control and pretreated samples with O_3 at 10 and 20 µL L^{-1}, comparing to
687 samples stored for 45 days. This stem browning could be correlated to the
688 condensation of CO_2 inside package (Crisosto et al., 2002a, Chen et al., 2011, Candir
689 et al., 2012, Teles et al., 2014), produced by the accelerated respiration of the
690 products generated mainly by the stress of high temperature during SL.

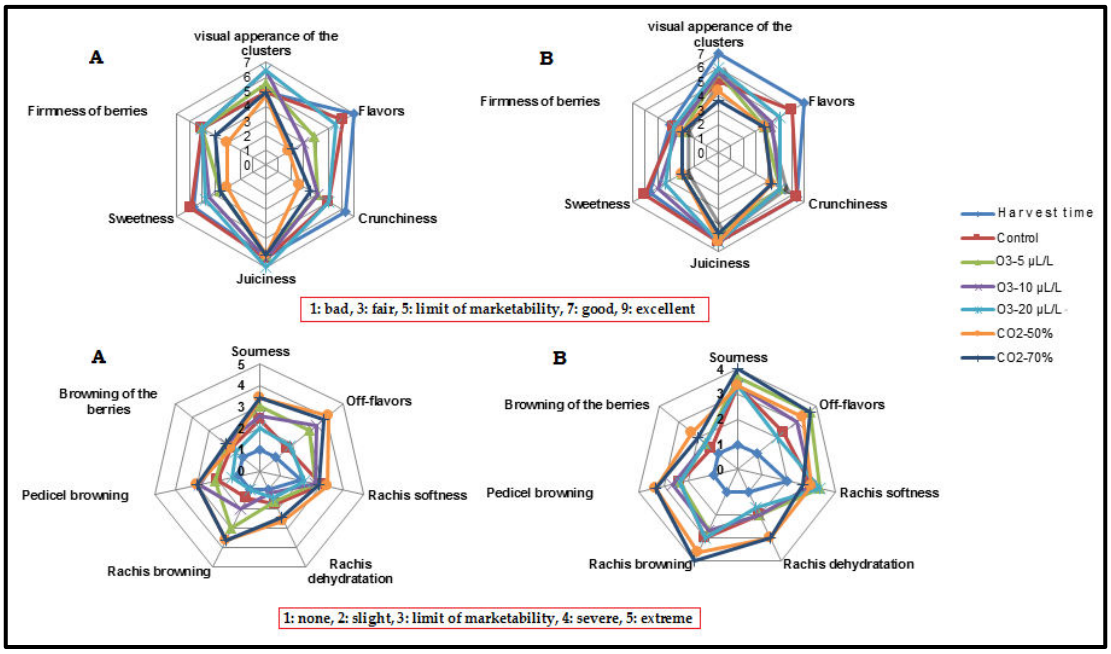

Figure 6. Effects of pretreatments and MAP on organic table grapes cv. Scarlotta® sensory quality after CS (A) and SL (B).

4 Conclusion

The efficiency of modified atmosphere (MA) and film barrier properties was highlighted to reduce water loss and maintain mechanical and chemical characteristics on late-season organic table grapes (Scarlotta®) throughout a long conservation according to market requirements for 55 days of CS and one week of simulated commercial SL. O_3 could be a commercial alternative to the use of SO_2 generators for keeping an acceptable visual appearance of cluster close to that at harvest and increased total anthocyanin accumulation, total phenol content and antioxidant activity during CS. Moreover, pretreatment with O_3 at 20 µL L^{-1} was the most effective for controlling decay incidence by maintaining EU commercial standards until 55 days of CS and one week of SL, preventing stem browning and off-flavor production, in addition a good preserving of sensory quality and skin color with positive influence on the pathways leading to the synthesis of the different anthocyanins. Thus, combination of pretreatment with O_3 at 20 µL L^{-1} and MAP

709 during storage, transportation or marketing could be a commercially practical
710 alternative for postharvest handling of organic grapes. Therefore, further trials with
711 other cultivars should be worth to validate the applied protocol.

712 ## References

713 Acevado De la Cruz, A., Hilbert, G., Rivière, C., Mengin, V., Ollat, N.,
714 Bordenave, L., Decroocq, S., Delaunay, J.C., Delrot, S., Mérillon, J.M., Monti.
715 J.P., Gomès, E., Richard, T., 2012. Anthocyanin identification and composition
716 of wild Vitis spp. accessions. Anal. Chim. Acta. 732, 145-152.

717 Admane, N., Altieri, G., Genovese, F., Di Renzo, G.C., Verrastro, V., Tarricone,
718 L, Ippolito, A., 2015. Application of High Carbon Dioxide or Ozone Combined
719 with MAP on Organic Late-Season 'Scarlotta Seedless ®' Table Grapes. Acta
720 Hort. (ISHS). 1079, 193-199.

721 Anon., 1986. GRAS status of sulfating agents for use on fresh and frozen foods
722 revoked. Fed. Regist. 5, 25021.

723 Artés, F., 1976. Estudio y aplicacion de membranas de polimeros paragenerar y
724 estabilizar atmosferas modificadas. CEBAS-CSIC, Murcia, Spain, pp. 294.

725 Artés-Hernández, F., Aguayo, E., Artés, F., 2004. Alternative gas treatments for
726 keeping quality of 'Autumn seedless' table grapes during long term cold storage.
727 Postharvest Biol. Technol. 31, 59-67.

728 Artés-Hernández, F., Aguayo, E., Artés, F., Tomás-Barberán, F.A., 2007.
729 Enriched ozone atmosphere enhances bioactive phenolics in seedless table grapes
730 after prolonged shelf life. J. Sci. Food Agric. 87, 824-831.

731 Artés-Hernández, F., Artés, F., Tomás-Barberán, F.A., 2003. Quality and
732 enhancement of bioactive phenolics in cv. Napoleon table grapes exposed to
733 different postharvest gaseous treatments. J. Agric. Food Chem. 51, 5290-5295.

734 Artés-Hernández, F., Tomás-Barberán, F.A., Artés, F., 2006. Modified
735 atmosphere packaging preserves quality of SO_2-free 'Superior seedless' table
736 grapes. Postharvest Biol. Technol. 39, 146-154.
737 Baiano, A., Lamacchia, C., Previtali, M.A., Tufariello, M., Arace, E., Notte, E.L.,
738 2007. Influence of post-harvest treatments on the quality of table grape from
739 Apulia (Italy).
740 <http://www.oiv2007.hu/documents/viticulture/247_baiano_poster.pdf>
741 Balic, I., Moreno, A., Sanhueza, D., Huerta, C., Orellana, A., Defilippi, B.G.,
742 Campos-Vargas R., 2012. Molecular and physiological study of postharvest
743 rachis browning of table grape cv Red Globe. Postharvest Biol. Technol. 72, 47-
744 56.
745 Caleb, J.O., Mahajan, V.P., Al-Said, A.F., Opara, L.U., 2013. Modified
746 atmosphere packaging technology of fresh and fresh-cut produce and the
747 microbial consequences-a review. Food Bioprocess Technol. 6, 303-329.
748 Cameron, A.C., Beaudry, R.M., Banks, N.H., Yelanich, M.V., 1994. Modified
749 atmosphere packaging of blueberry fruit: modelling respiration and package
750 oxygen partial pressures as function of temperature. J. Am. Soc. Hortic. Sci. 119,
751 534-539.
752 Candir, E., Ozdemir, A.E., Kamiloglu, O., Soylu, E.M., Dilbaz, R., Ustun, D.,
753 2012. Modified atmosphere packaging and ethanol vapor to control decay of
754 'Red Globe' table grapes during storage. Postharvest Biol. Technol. 63, 98-106.
755 Cantos, E., Espin, J.C., Barberan, F.A.T., 2002. Varietal differences among the
756 polyphenol profiles of seven table grape cultivars studied by LC-DAD-MS-MS.
757 J. Agric. Food Chem. 50, 5691-5696.

758 Carreño, J., Martínez, A., Almela, L., Fernández-López, J.A., 1996. Measuring
759 the color of table grapes. Color Res. Appl. 21, 50-54.
760 Carreño, J., Martinez, A., Almela, L., Fernhndez-López, J.A., 1995. Proposal of
761 an index for the objective evaluation of the colour of red table grapes. Int. Food
762 Res. J. 28, 373-377.
763 Carvajal-Millán, E., Carvallo, T., Orozco, J., Martínez, M., Tapia, I., Guerrero,
764 V., Rascón-Chu, A., Llamas, J., Gardea, A., 2001. Polyphenol oxidase activity,
765 color changes, and dehydration in table grape rachis during development and
766 storage as affected by N-(2-chloro-4-pyridyl)-N-phenylurea. J. Agric. Food
767 Chem. 49, 946–951.
768 Cayuela, J.A., Vazquez, A., Perez, A.G., Garcia, J.M., 2009. Control of table
769 grapes postharvest decay by ozone treatment and resveratrol induction. Food Sci.
770 Tech. Inst. 15, 495-502.
771 Chen, S., Zhang, M., Wang, S., 2011. Effect of initial hermetic sealing on quality
772 of ‘Kyoho’ grapes during storage. Postharvest Biol. Technol. 59, 194-199.
773 Chervin, C., Aked, J., Crisosto, C.H., 2012. Grapes, in: Rees, D., Farrell, G.,
774 Orchard, J. (Eds.), Crop post-Harvest: Science and Technology. Blackwell
775 Publishing Ltd., Oxford, OX4 2DQ, UK, pp. 187–211.
776 Chervin, C., Westercamp, P., Monteils, G., 2005. Ethanol vapours limit Botrytis
777 development over the postharvest life of table grapes. Postharvest Biol. Technol.
778 36, 319-322.
779 Ciccarese, A., Stellacci, A.M., Gentilesco, G., Rubino, P., 2013. Effectiveness of
780 pre- and post-veraison calcium applications to control decay and maintain table
781 grape fruit quality during storage. Postharvest Biol. Technol. 75, 135-141.

782 Crank, J, Park, G.S., 1968. Diffusion in polymers. London, Academic Press, pp.
783 360.
784 Crisosto, C.H., Garner, D., Crisosto, G., 2002a. Carbon dioxide-enriched
785 atmospheres during cold storage limit losses from Botrytis but accelerate rachis
786 browning of 'Redglobe' table grapes. Postharvest Biol. Technol. 26, 181-189.
787 Crisosto, C.H., Garner, D., Crisosto, G., 2002b. High carbon dioxide atmospheres
788 affect stored 'Thompson Seedless' table grapes. Hortscience. 37, 1074-1078.
789 Crisosto, C.H., Mitchell, F.G., 2002. Postharvest handling systems: small fruits.
790 Table grapes, in: Kader, A. (Ed.), Postharvest Technology of Horticulture Crops.
791 University of California, Agriculture and Natural Resources, Oakland, pp. 357-
792 363.
793 Exama, A., Arul, J., Lencki, R.W., Lee, L.Z, Toupin, C., 1993. Suitability of
794 plastic Films for modified atmosphere packaging of fruits and vegetables. J. Food
795 Sci. 58, 1365-1370.
796 Ferrara, G., Mazzeo, A., Matarrese, A.M.S., Pacucci, C., Punzi, R., Faccia, M.,
797 Trani, A., Gambacorta, G., 2015. Application of abscisic acid (S-ABA) and
798 sucrose to improve colour, anthocyanin content and antioxidant activity of cv.
799 Crimson Seedless grape berries. Aust. J. Grape Wine Res. 21, 18-29.
800 Fonseca, S.C., Oliveira F.A.R., Brecht, J.K., 2002. Modelling respiration rate of
801 fresh fruits and vegetables for modified atmosphere packages: a review. J. Food
802 Eng. 52, 99-119.
803 Gambacorta, G., Antonacci, D., Pati, S., La Gatta, M., Faccia, M., Coletta, A., La
804 Notte, E., 2011. Influence of winemaking technologies on phenolic composition
805 of Italian red wines. Eur. Food Res. Technol. 233, 1057-1066.

Hagenmaier, R.D., 2005. A comparison of ethane, ethylene and CO_2 peel permeance for fruit with different coatings. Postharvest Biol. Technol. 37, 56-64.

Haggar, P.E., D.S. Lee, Yam, K.L., 1992. Application of an enzyme kinetics based respiration model to closed system experiments for fresh produce. J. Food Proc. Eng. 15,143-157.

Hörtensteiner, S., Kräutler, B., 2011. Chlorophyll breakdown in higher plants. BBA Bioenerg. 1807, 977-988.

Jayas, D.S., Jeyamkondan, S., 2002. Modified atmosphere storage of grains meats fruits and vegetables. Biosyst. Eng. 82, 235-251.

Kader, A.A., Zagory, D. Kerbel, E.L., 1989. Modified atmosphere packaging of fruits and vegetables. Crit. Rev. Food Sci. Nutr. 28, 1-30.

Karaca, H., Walse, S.S., Smilanick, J.L., 2012. Effect of continuous 0.3 μL L-1 gaseous ozone exposure on fungicide residues on table grape berries. Postharvest Biol. Technol. 64, 154-159.

Khadre, M.A., Yousef, A.E., Kim, J.G., 2001. Microbial aspects of ozone applications in food: a review. J. Food Sci. 66, 1242-1252.

Lamikanra, O., 2002. Fresh-cut fruits and vegetables: science, technology, and market. Boca Raton, Fla., CRC Press., pp. 480.

Larsen, H., Kohler, A., Magnus, E.M., 2000. Ambient Oxygen Ingress Rate Method-An Alternative Method to Ox-Tran for Measuring Oxygen Transmission Rate of Whole Packages. Packag. Technol. Sci. 13, 233-241.

Lee, D.S., Haggar, P.E., Lee, J., Yam, K.L., 1991. Model for fresh produce respiration in modified atmospheres based on principles of enzyme-kinetics. J. Food Sci. 56,1580-1585.

Lee, J., 1987. The design of controlled or modified packaging systems for fresh produce, in: Gray, J.I., Harte, B.R., J. Miltz (eds.), Food product-package compatibility proceedings. Technomic Publishing, Lancaster, Pa, pp. 157.

Liang, Z., Owens, C.L., Zhon, G., Cheng, L., 2011. Polyphenolic profiles detected in the ripe berries of Vitis vinifera germplasm. Food Chem. 129, 940-950.

Lichtenthaler, H.K., 1987. Chlorophylls and Carotenoids: Pigments of Photosynthetic Biomembranes. Methods in Enzymology. Academic Press. 147, 350-382.

Lichter, A., 2016. Rachis browning in tablegrapes. Aust. J. Grape Wine Res. 22, 161-168.

Lichter, A., Kaplunov, T., Zutahy, Y., Daus, A., Alchanatis, V., Ostrovsky, V., Lurie, S., 2011. Physical and visual properties of grape rachis as affected by water vapor pressure deficit. Postharvest Biol. Technol. 59, 25-33.

Lichter, A., Mlikota Gabler, F., Smilanick, J.L., 2006. Control of spoilage in table grapes. Stewart Postharvest Review. 2, 1-10.

Lutz, M., Jorquera, K., Cancino, B., Ruby, R., Henriquez, C., 2011. Phenolics and Antioxidant Capacity of Table Grape (Vitis vinifera L.) Cultivars Grown in Chile. J. Food Sci. 76, C1088-C1093.

Luvisi, D., Shorey, H., Smilanick, J.L., Thompson, J., Gump, B.H., Knutson, J., 1992. Sulfur dioxide fumigation of table grapes. Bulletin 1932, University of California, Division of Agriculture and Natural Resources, Oakland, CA, USA, pp. 21.

853 Martínez-Romero, D., Guillén, F., Castillo, S., Valero, D., Serrano, M., 2003.
854 Modified Atmosphere Packaging Maintains Quality of Table Grapes. J. Food Sci.
855 68, 1838-1843.
856 Minas, I.S., Karaoglanidis, G.S., Manganaris, G.A., Vasilakakis, M., 2010. Effect
857 of ozone application during cold storage of kiwifruit on the development of stern-
858 end rot caused by Botrytis cinerea. Postharvest Biol. Technol. 58, 203-210.
859 Mlikota Gabler, F., Smilanick, J.L., 2001. Postharvest control of table grape gray
860 mold on detached berries with carbonate and bicarbonate salts and disinfectants.
861 J. Enol. Vitic. 52, 12-20.
862 Mlikota Gabler, F., Smilanick, J.L., Ghosoph, J.M., Margosan, D.A., 2005.
863 Impact of Postharvest Hot Water or Ethanol Treatment of Table Grapes on Gray
864 Mold Incidence, Quality, and Ethanol Content. Plant Dis. 89, 309-316.
865 Mlikota Gabler, F., Smilanick, J.L., Mansour, M.F., Karaca, H., 2010. Influence
866 of fumigation with high concentrations of ozone gas on postharvest gray mold
867 and fungicide residues on table grapes. Postharvest Biol. Technol. 55, 85-90.
868 Ngcobo, M.E.K., Delele, M.A., Pathare, P.B., Chen, L., Opara, U.L., Meyer, C.J.,
869 2012. Moisture loss characteristics of fresh table grapes packed in different film
870 liners during cold storage. Biosyst. Eng. 113, 363-370.
871 Pastrana-Bonilla, E., Akoh, C.C., Sellappan, S., Krewer, G., 2003. Phenolic
872 content and antioxidant capacity of Muscadine grapes. J. Agric. Food Chem. 51,
873 5497-5503.
874 Pesis, E., 2005. The role of the anaerobic metabolites, acetaldehyde and ethanol,
875 in fruit ripening, enhancement of fruit quality and fruit deterioration. Postharvest
876 Biol. Technol. 37, 1-19.

877 Piazzolla, F., Pati, S., Amodio, M.L., Colelli, G., 2015. Effect of harvest time on
878 table grape quality during on-vine storage. J. Sci. Food Agric. 96, 131-139.
879 Re, R., Pellegrini, N., Pannala, A., Yang, M., Rice-Evans, C., 1999. Antioxidant
880 activity applying an improved ABTS radical cation decolorization assay. Free
881 Radic. Biol. Med. 26, 1231-1237.
882 Retamales, J., Defilippi, B.G., Arias, M., Castillo, P., Manriquez, D., 2003. High-
883 CO2 controlled atmospheres reduce decay incidence in Thompson Seedless and
884 Red Globe table grapes. Postharvest Biol. Technol. 29, 177-182.
885 Revilla, E., Ryan, L.M., 2000. Analysis of several phenolic compounds with
886 potential antioxidant properties in grape extracts and wines by high-performance
887 liquid chromatography-photodiode array detection without sample preparation. J.
888 Chromatogr. A 881, 461-469.
889 Romanazzi, G., Lichter, A., Mlikota Gabler, F., Smilanick, J.L., 2012. Recent
890 advances on the use of natural and safe alternatives to conventional methods to
891 control postharvest gray mold of table grapes. Postharvest Biol. Technol. 63,
892 141-147.
893 Romero, I., Fernandez Caballero, C., Sanchez-Ballesta, M.T., Escribano, M.I.,
894 Merodio, C., 2009. Influence of the stage of ripeness on phenolic metabolism and
895 antioxidant activity in table grapes exposed to different CO_2 treatments.
896 Postharvest Biol. Technol. 54, 118-121.
897 Romero, I., Sanchez-Ballesta M.T., Maldonado, R., Isabel Escribano, M.,
898 Merodio, C., 2008. Anthocyanin, antioxidant activity and stress-induced gene
899 expression in high CO2-treated table grapes stored at low temperature. J. Plant
900 Physiol. 165, 522-530.

Sanchez-Ballesta, M.T., Jiménez, J.B., Romero, I., Orea, J.M., Maldonado, R., Ureña, Á.G., Escribano, M.I., Merodio, C., 2006. Effect of high CO_2 pretreatment on quality, fungal decay and molecular regulation of stilbene phytoalexin biosynthesis in stored table grapes. Postharvest Biol. Technol. 42, 209-216.

Sanchez-Ballesta, M.T., Romero, I., Jiménez, J.B., Orea, J.M., González-Ureña, Á., Escribano, M.I., Merodio, C., 2007. Involvement of the phenylpropanoid pathway in the response of table grapes to low temperature and high CO_2 levels. Postharvest Biol. Technol. 46, 29-35.

Sharpe, D., Fan, L., McRae, K., Walker, B., Mackay, R., Doucette, C., 2009. Effects of ozone treatment on Botrytis cinerea and Sclerotinia sclerotiorum in relation to horticultural product quality. J. Food Sci. 74, 250-257.

Shioi, Y., Tomita, N., Tsuchiya, T., Takamiya, K.-I., 1996. Conversion of chlorophyllide to pheophorbide by Mg-dechelating substance in extracts of Chenopodium album. Plant Physiol. Bioch. 34, 41-47.

Silva-Sanzana, C., Balic, I., Sepúlveda, P., Olmedo, P., León, G., Defilippi, B.G., Blanco-Herrera, F., Campos-Vargas, R., 2016. Effect of modified atmosphere packaging (MAP) on rachis quality of 'Red Globe' table grape variety. Postharvest Biol. Technol. 119, 33-40.

Singh Brar, H., Singh, Z., Swinny, E., 2008. Dynamic of anthocyanin and flavonol profiles in the 'Crimson Seedless' grape berry skin during development and ripening. Sci. Hortic. 117. 349-356.

Smilanick, J.L., Hartsell, P.I., Henson, D., Fouse, D.C., Assemi, M., Harris, C.M., 1990. Inhibitory activity of sulfur-dioxide on the germination of spores of Botrytis cinerea. Phytopathology. 80, 217-220.

926 Smilanick, J.L., Mlikota Gabler, F., Margosan, D., 2010. Influence of continuous,
927 low concentration ozone during cold storage on postharvest decay and quality of
928 table grapes. In: Proceedings “6th International Table grape Symposium”, Davis,
929 CA, USA, pp. 85-86.
930 Suzuki, T., Kunieda, T., Murai, F., Morioka, S., Shioi, Y., 2005. Mg-dechelation
931 activity in radish cotyledons with artificial and native substrates: mg-
932 chlorophyllin a and chlorophyllide a. Plant Physiol. Biochem. 43, 459-464.
933 Teles, C.S., Benedetti, B.C., Gubler, W.D., Crisosto, C.H., 2014. Prestorage
934 application of high carbon dioxide combined with controlled atmosphere storage
935 as a dual approach to control Botrytis cinerea in organic "Flame Seedless" and
936 "Crimson Seedless" table grapes. Postharvest Biol. Technol. 89, 32-39.
937 US Food and Drug Administration (US FDA), 2001. Title 21: Food and Drugs
938 Part 173. Secondary direct food additives permitted in food for human
939 consumption subpart D, specific usage additives. Fed. Reg., 66, 33829.
940 Ustun, D., Candir, E., Ozdemir, A.E., Kamiloglu, O., Soylu, E.M., Dilbaz, R.,
941 2012. Effects of modified atmosphere packaging and ethanol vapor treatment on
942 the chemical composition of ‘Red Globe’ table grapes during storage. Postharvest
943 Biol. Technol. 68, 8-15.
944 Valero, D., Valverde, J. M., Martínez-Romero, D., Guillén, F., Castillo, S.,
945 Serrano, M., 2006. The combination of modified atmosphere packaging with
946 eugenol or thymol to maintain quality, safety and functional properties of table
947 grapes. Postharvest Biol. Technol. 41, 317-327.
948 Valverde, J.M., Valero, D., Martínez-Romero, D., Guillén, F., Castillo, S.,
949 Serrano, M., 2005. Novel edible coating based on Aloe vera gel to maintain table
950 grape quality and safety. J. Agric. Food Chem. 53, 7807-7813.

951 Vincente Ariel, R., Manganaris George, A., Ortiz Cristian, M., Sozzi Gabriel, O.,
952 Crisosto Carlos, H., 2014. Nutritional Quality of Fruits and Vegetables, in:
953 Von Gunten U., 2003. Ozonation of drinking water: Part II. Disinfection and by-
954 product formation in presence of bromide, iodide or chlorine. Water Res. 37,
955 1469-1487.
956 Wilson, C.L., 1997. Biological control and plant diseases- a new paradigm. J.
957 Ind. Microbiol. Biotechnol. 19, 158-159.
958 Zoffoli, J.P., Latorre, B.A., Naranjo, P., 2008. Hairline, a postharvest cracking
959 disorder in table grapes induced by sulfur dioxide. Postharvest Biol. Technol. 47,
960 90-97.