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Influence of modified atmosphere packaging on postharvest quality of cherry tomatoes held at 20 °C

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ABSTRACT

The effects of passive modified atmosphere packaging (MAP) achieved with a 30 μm thick continuous oriented polypropylene (OPP) film (Film A) or by the same film either laser-perforated with increasing levels of perforation (Films B–E) or macro-perforated (Film F) on overall qualitative changes and decay was studied on cherry tomatoes cv 'Dorotea' and 'Trebus' harvested at the red-ripe stage and stored for 7, 14 or 21 d at 20 °C 60% RH. Respiratory activity of both cultivars decreased as permeability of macro- and laser-perforated films decreased but increased in tomatoes sealed with Film A, which led to anaerobic conditions. In laser perforated films average in-package CO_2 and O_2 were around 3 kPa and above 15 kPa, respectively, with moderate variations among Films B–E, while in Film A average CO_2 and O_2 were around 12 kPa and 6 kPa, respectively. In-package gas composition of Film F only slightly differed from air. Air composition and high in-package humidity of laser perforated films controlled water loss and delayed loss of firmness and of titratable acidity, total soluble solids, vitamin C, but increased decay of the very susceptible to cracking 'Dorotea' tomatoes. The high in-package CO_2 of Film A reduced pathogens growth, but decay incidence was lowest in unwrapped tomatoes and packages of Film F. 'Trebus' tomatoes were more resistant to decay than 'Dorotea' ones. MAP with moderate levels of CO_2 (around 3 kPa), O_2 not below than 12 kPa and RH not higher than 90% could prolong overall quality and reduce decay of red-ripe cherry tomatoes at 20 °C.

1. Introduction

In the last decade snacking tomatoes, including cherry tomatoes, have increased in popularity due to their high content of sugars, health promoting compounds and convenience of use, being consumed both as a vegetable in salads and as a fruit (Raffo et al., 2002).

Tomatoes are highly perishable and, as for most climacteric fruits, anticipating harvest before the climacteric rise is considered the best strategy to prolong shelf-life and reduce spoilage rate (Saltveit, 2005). However, this practice can negatively affect taste and nutritional quality as fruit picked at the mature green stage or before turning to red color, although able to continue the ripening process, develop poor eating and nutritional traits when fully ripened (Kader, 1986).

Loss of sensory quality in tomatoes is associated with reduction of sweetness and acidic taste, flavor intensity and firmness (Grierson and Kader, 1986). Firmness is strongly related to weight loss and, in turn, to transpiration rate, which in cherry tomatoes, due to the high ratio between surface and weight of the berry can be very high especially at marketing conditions.

Modified atmosphere packaging (MAP) (Mangaraj et al., 2009; Mir and Beaudry, 2014) and controlled atmosphere (CA) storage (Kader, 1986) of fresh produce have long been used as a means to prolong shelf-life by reducing the overall physiological activity, minimizing mechanical damages and alleviating water stress in many postharvest commodities as well as in tomatoes. Optimal combination of CO_2 and O_2 can widely vary with cultivars. A CA with 3 kPa O_2 + 2 kPa CO_2 is considered as satisfactory for tomatoes (Wills et al., 1998). Saltveit (1997) observed only slight or moderate beneficial effects of CA in mature green or red tomatoes and indicated in 3–5 kPa O_2 + 2–3 kPa CO_2 for mature green tomatoes and 3–5 kPa O_2 + 3–5 kPa CO_2 for red tomatoes the best gas combinations for controlled atmosphere storage. However, most

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studies on CA or MAP have been done on tomatoes types other than cherry tomatoes. Also, in those studies fruit were harvested at the pre-climacteric stage and stored at the lowest temperature in order to avoid chilling injury.

Cherry tomatoes are generally harvested when deep red and destined directly to fresh market. Thus, in most cases, during the postharvest life, apart a likely brief exposure to low temperatures during transportation, they are held at typical retail outlet display temperatures, which are around 20 °C. The fact that cherry tomatoes are harvested at the post-climacteric phase and that fruit are much smaller than those of other cultivars studied previously leads to question as to whether the postharvest behavior between cherry tomatoes and other type of tomatoes is comparable.

As many of MAP systems are designed for tomatoes to be held at between 5 and 10 °C (Bailèn et al., 2006; Fagundes et al., 2015), transfer to warmer environments like retail displays or household racks may create fermentative conditions because respiration increases more than permeation of the packages (Mangaraj et al., 2009) and also because the tolerance to low O_2 levels and high concentration of CO_2 decreases with the increase in temperature (Beaudry et al., 1992).

Thus, objective of this study was to assess how different MAP specifications affected respiration, ethylene production rates and overall physical–chemical quality of cherry tomatoes harvested when full ripe and held continually at 20 °C, in order to determine a range of in-package gases conditions easily achievable with popular polymeric films in solid or micro-perforated formats.

With the aim of getting a range of conditions valid for most cherry tomatoes cultivars this study was done using two cultivars markedly different for many physiological aspects; that is to say a typical climacteric cultivar, 'Dorotea' characterized by a quite high perishability and a long shelf-life cultivar, 'Trebus'. The physiological activity together with the overall visual quality, the changes in chemical compounds and their susceptibility to microbiological spoilage were studied and assessed over a three-week storage time.

2. Materials and methods

2.1. Plant material

Two cherry tomato (*Lycopersicon esculentum* var. cerasiforme) cultivars, 'Trebus', a long shelf-life type, and 'Dorotea', a climacteric type, were harvested according to local standard marketing maturity stage, which corresponds to the red-ripe stage, from a greenhouse located in San Sperate (South Sardinia). Within three hours from harvest, fruit, transported to the laboratory in Sassari by air conditioned car, were separated from the cluster by pulling each fruit from the calyx and selected for experimentation by removing all those showing any visual defects including cracking, which developed within two hours from calix removal.

2.2. Modified atmosphere packaging and storage conditions

Fruit were packaged in plastic trays by sealing a 30-μm-thick oriented polypropylene (OPP) film perforated 40 times with a 2-mm-diameter needle (Film F) or by the same film either continuous (Film A) or with four increasing levels of laser perforation (Films B–E) in order to get increasing levels of permeance to O_2, CO_2 and water vapor (Table 1). Laser perforations were done in one line along the film, with holes averaging 97 μm in diameter and distant from each other 13–62 mm according to the level of perforation. All six films were provided by Svenskt Pacsystem AB (Helsingborg, Sweden).

The oxygen permeance of the OPP film was measured by the producer of the film, while the CO_2 permeance was measured by the method described in Mistriotis et al. (2016). The WVTR of the non-perforated OPP film was gravimetrically measured by using the ASTM-E96/E96-05 standard. The transmission rates of the perforated films were calculated by using the modified Fick's law describing diffusion through perforations (Chung et al., 2003).

Each package, filled with 15 fruit, weighed approximately 250 g. The volume of the trays was 500 mL, while the volume of the whole package after applying the film loose over the tray, was 900–1000 mL. For each treatment, cultivar and storage time 20 packages were prepared, for a total of 840 packages, of which 120 packages unwrapped served as control. Fruit were stored at 20 °C and environmental humidity of 60–65% RH for 7, 14 or 21 days. At each inspection time, 20 packages of each treatment and cultivar were opened and fruit were used for assessments and analyses.

Additional packages using all six films with fruit dipped for 60 s in a fungicidal solution at 20 °C containing 600 mg L^{-1} fludioxonil (Scholar, Syngenta Crop Protection, Milan, Italy) before packaging to prevent decay, were prepared to determine respiratory activity, ethylene production rates, in-package gas composition and monitor in-package humidity and temperature. Respiration and ethylene production were always determined using the same packages; similarly, another set of packages was used to determine in-package air composition. In both cases the number of packages for each treatment and cultivar were six. To monitor in-package temperature and humidity, a data logger (LogTag Humidity & Temperature Recorder, Auckland, New Zealand) was placed inside three packages for each treatment and cultivar and set to record temperature and relative humidity every four hours; three additional data loggers were placed in different places of the storage room to monitor humidity and temperature in the storage environment.

2.3. Ethylene production rates and respiration

Wrapped and unwrapped trays (15 fruit per tray) were placed into 3-liter jars, whose lids were fitted with two silicon septa and closed for 2 h. At sampling time, the headspace air was mixed for 1 min by an electrical fan fixed inside the jar and then a 2-mL

Table 1
Barrier properties of the used films.

Film	O_2 permeance (O_2p)[a] (μM s^{-1} m^{-2} kPa^{-1})	CO_2 permeance (CO_2p) (μM s^{-1} m^{-2} kPa^{-1})	Selectivity CO_2p O_2p^{-1}	WVTR (μg s^{-1} m^{-2}) when RH difference is 50%
A	0.0087	0.042f[b]	4.83	6.02f
B	0.370	0.323e	0.87	20.37e
C	0.813	0.668d	0.82	37.85d
D	1.264	1.019c	0.81	55.79c
E	1.743	1.392b	0.80	74.77b
F	11.24	8.781a	0.78	373.84a

[a] Values provided by the producers.
[b] Values in column followed by unlike letters are significantly different at $P \leq 0.05$ according to Duncan's multiple range test ($n = 3$).