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Influence of Ethylene Inhibition by 1-Methylcyclopropene on Apricot Quality, Volatile Production, and Glycosidase Activity of Low- and High-Aroma Varieties of Apricots

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Apricots of two varieties, Ceccona with strong aroma and San Castrese with low aroma but good firmness, were treated with 1 μL L^{-1} 1-methylcyclopropene (1-MCP) for 12 h at 20 °C and then kept for shelf life at 20 °C and 85% relative humidity. 1-MCP treatment strongly inhibited ethylene production in apricots of both varieties, and softening was delayed. Fruit softening started before the rise of ethylene in air-treated apricots, which softened even when the rise of ethylene production was inhibited by 1-MCP. The softening reduction was more significant in Ceccona apricots than in San Castrese. Pectinmethylesterase (PME) activity declined in Ceccona fruit regardless of the treatment; in San Castrese, PME of air-treated fruit slightly increased, whereas in 1-MCP-treated apricots the activity declined. α-D-Galactosidase (α-gal) and β-D-galactosidase (β-gal) activities in Ceccona apricot were significantly reduced by 1-MCP treatment, whereas in San Castrese apricot no difference in activities was observed between air- and 1-MCP-treated fruit. The pattern of β-D-xylosidase (xyl) activity in San Castrese apricot was similar to that of β-gal, showing a peak on day 4 without difference between treatments. α-D-Mannosidase (α-man) activity of air-treated apricots of both varieties rose slightly, and 1-MCP treatment decreased the enzyme activity in both varieties. α-D-Glucosidase (α-glu) decreased in air-treated apricots in both varieties, and 1-MCP maintained higher activity in Ceccona fruit but not in San Castrese. Acidity decreased during postharvest ripening regardless of the treatment, whereas soluble solids content (SSC) increased in Ceccona apricot and slightly diminished in San Castrese ones without any effect by 1-MCP treatment. 1-MCP did not show any effect on apricot color; in contrast, it affected the volatiles profile, especially in Ceccona apricot, reducing the synthesis of lactones and promoting the rise of terpenols.

KEYWORDS: Apricots; 1-MCP; glycosidases; volatiles; ethylene; softening

INTRODUCTION

Apricot fruits are appreciated by consumers for their flavor, sweetness, and juiciness. These characteristics are strongly related to the variety and ripening stage at harvest. Early harvest of apricots is a common practice because it makes for easy handling and shipping, but the apricot-like aroma is developed only if the fruits are not maintained at low temperature (*1*). Harvest of riper fruit provides apricots with more aroma, but their shelf life is short unless they are kept at low temperature or at 18 °C in 1% O_2. Moreover, the soft fruits are easily damaged, including latent damage (*2*). The main problem during marketing of apricots is excessive softening, but little is known of the mechanism of softening in these fruits, and even the role of ethylene is unclear. It has been reported that propylene treatment hastens the softening (*3*, *4*), but it has been noted in peach and in apricots that softening begins before the rise in ethylene production (*5*, *6*).

Fruit softening is associated with higher pectin solubility and sugar loss from cell wall fractions (*7*, *8*). Rose and Bennet (*9*) have postulated that expansin could make the cell wall prone to the activity of the glycosidases that increase during ripening of apricots (*10*). Glycosidases progressively hydrolyze mono- and disaccharides from the nonreducing ends of oligo- or polysaccharides, and their action can contribute to the aroma development in *Prunus* for the release of monoterpenols such as nerol, linalool, geraniol, and α-terpineol (*11*). The aroma of apricots changes greatly depending on the variety with predominance of different volatiles group such as terpenols, esters, lactones, and C_6 compounds (*12*) and on the ripening stage (*13*).

1-Methylcyclopropene (1-MCP), a novel strong ethylene action inhibitor (*14*), has been observed to delay the ripening of cv. Perfection apricots, controlling the softening and also affecting fruit aroma (*13*). In cv. Canino apricot (*15*) the effect

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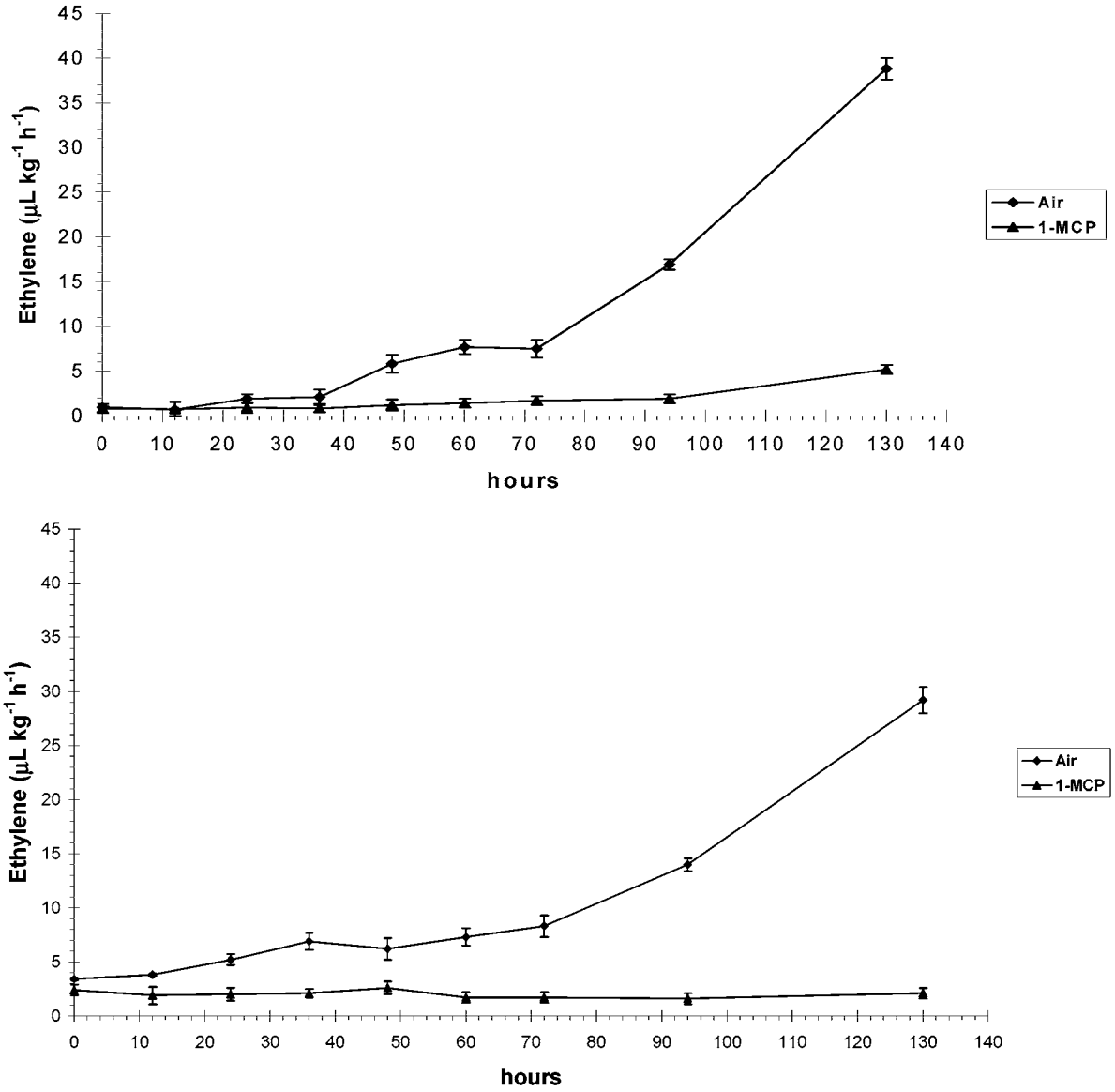

Figure 1. Ethylene production of cv. Ceccona (upper) and San Castrese (lower) apricots after treatment with 1 μL L^{-1} 1-MCP for 12 h at 20 °C in sealed glass jars, maintained for 130 h in air at 20 °C and 85% relative humidity. Air refers to untreated apricots maintained in air at the same thermohygrometric conditions. Data are the mean of three jars per reading. Vertical bars represent SD.

was significant only if the fruits were treated after the storage because the effect of 1-MCP was strongly dependent on the ethylene production rate. Chahine et al. (*3*) reported that 1-MCP reduced ethylene production of cv. Moniqui apricots but only at a preclimacteric stage of ripening.

The objective of the present study was to test strategies for using 1-MCP to provide firmer apricots with more aroma to the consumer. We used two apricot varieties, San Castrese, which has fruit that maintain its firmness during distribution but has relatively low aroma, and Ceccona, a traditional Italian variety, which is appreciated for their excellent aroma but which shows rapid softening. The apricots were picked at different ripening stages; the San Castrese fruits, which are known as firm apricots, were harvested at an advanced ripening stage to heighten their aroma development and then treated with 1-MCP to delay softening, whereas the Ceccona fruits, known for tendency to soften, were picked at an early ripening stage so that they were firmer fruits yet had acceptable aroma and were also treated with 1-MCP to test the possible inhibition of their normal rapid softening. Treated and control fruits were analyzed for physiological and quality features with special attention to pectinmethylesterase (PME) and glycosidase (*exo*-glycosylhydrolases) activities in relation to volatile production.

MATERIALS AND METHODS

Plant Materials and Treatments. San Castrese apricots were harvested at an advanced ripening stage (SSC = 14%), whereas Ceccona fruits were harvested at an early ripening stage (SSC = 10%). One hundred and sixty fruits from each variety, selected according to weight, size, and freedom from defects, were divided into two lots and placed at 20 °C in a temperature-controlled room. Eighty fruits for each variety were then placed in a 15 L glass jar, sealed with a lid adapted to allow the injection of 1-MCP (Agrofresh Inc., Milan, Italy). Preliminary experiments treating fruit for 12 h with 0.1, 0.5, 1, and 1.5 μL L^{-1} 1-MCP revealed that the lowest concentration did not affect ethylene production, whereas the highest one had the same effect as 1 μL L^{-1}, which was the concentration used in subsequent experiments. Control fruits (air-treated) were placed in similar sealed glass jars held in the same conditions. After the treatment, the jars were opened and the apricots were placed in plastic trays covered with plastic film, in the same room (20 °C and 85% relative humidity) for 6 days, depending on variety. By the end of treatment, CO_2 concentration in the jars was

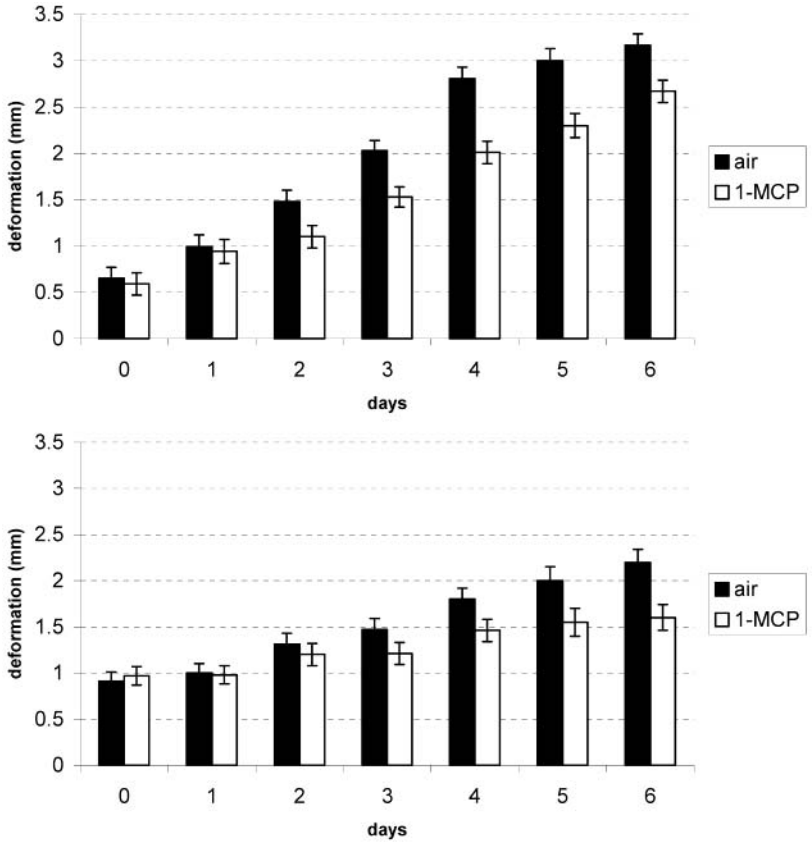

Figure 2. Fruit deformation during ripening of Ceccona (upper) and San Castrese (lower) apricots at 20 °C in air for 6 days. 1-MCP refers to apricots treated for 12 h with 1 μL L^{-1} in air at 20 °C. Data are the mean of 10 fruits plus SD; because the test was nondestructive, the same fruit were used for all tests.

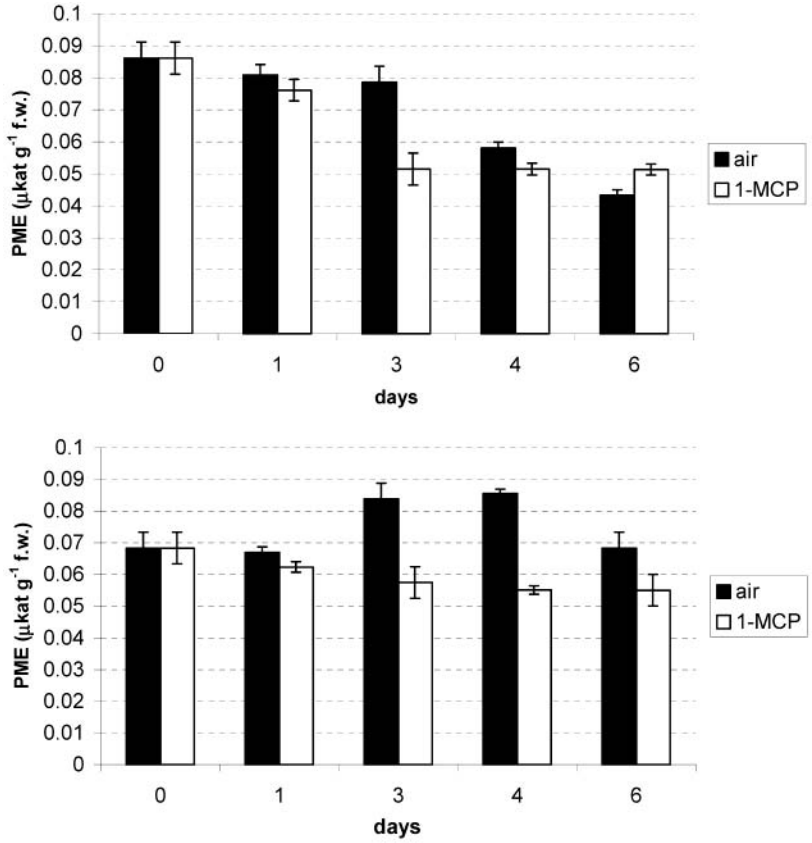

Figure 3. Pectinmethylesterase activity in cv. Ceccona (upper) and San Castrese apricots (lower) during ripening at 20 °C in air for 6 days. 1-MCP refers to apricots treated for 12 h with 1 μL L^{-1} in air at 20 °C. Data at each sampling time are the mean of three different apricots. Vertical bars represent SD.

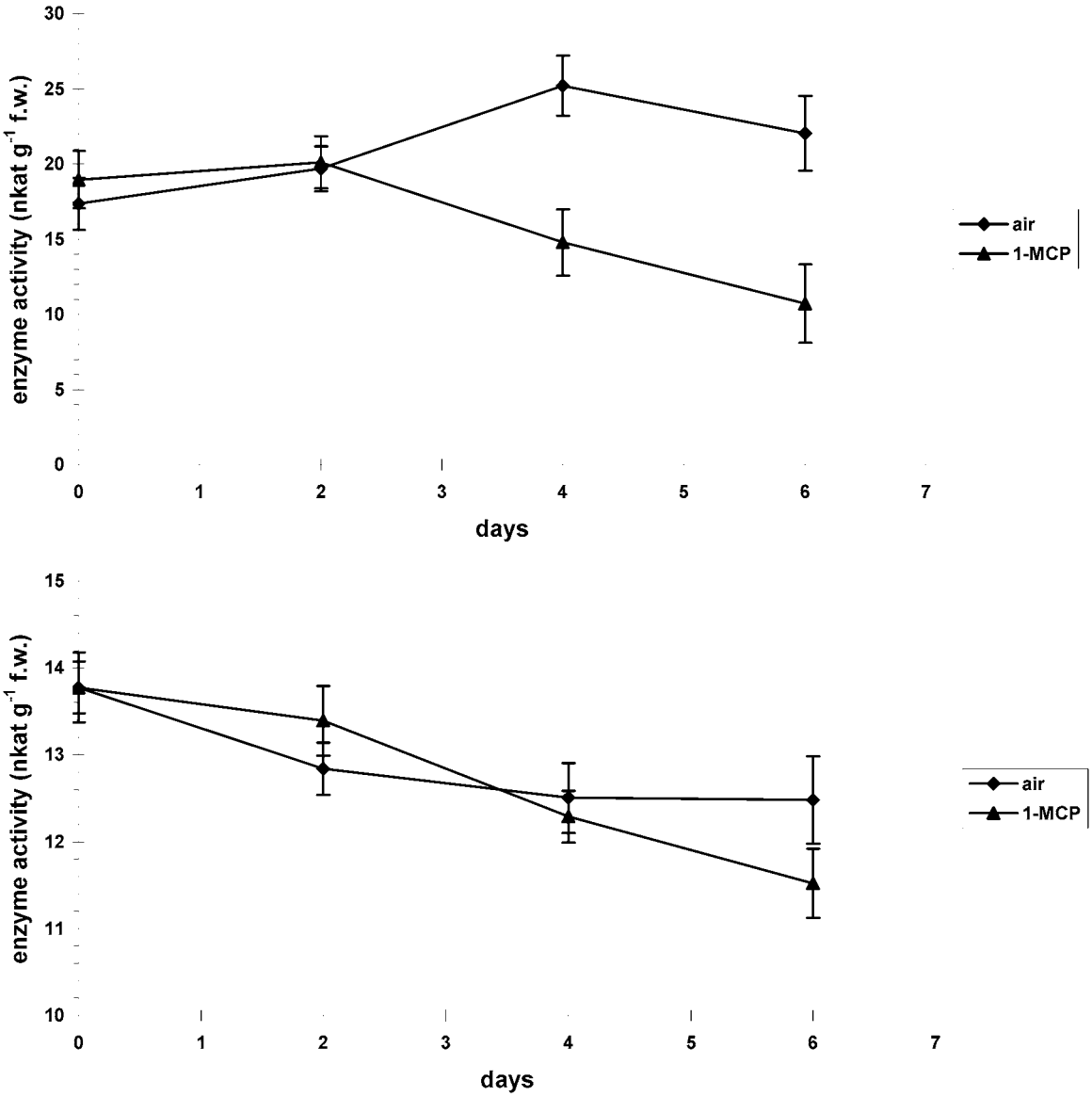

Figure 4. α-D-Galactosidase activity in cv. Ceccona (upper) and San Castrese (lower) apricots during ripening at 20 °C in air for 6 days. 1-MCP refers to apricots treated for 12 h with 1 μL L^{-1} in air at 20 °C. Data at each sampling time are the mean of three different apricots. Vertical bars represent SD.

~1%. The room was continuously ventilated at a sufficient rate to prevent any ethylene accumulation.

Ethylene Measurement. For C_2H_4 measurements, three samples of 10 fruits were sorted, each one placed into a 1 L glass jar sealed for 1 h, and C_2H_4 was monitored by injecting 1 mL of a headspace gas sample into a Carlo Erba Fractovap 4200 gas chromatograph (GC) (Carlo Erba Spa, Milano, Italy) equipped with a 1-m alumina column (80/100 mesh) with a flame ionization detector (Carlo Erba Spa), oven temperature = 100 °C. Results were expressed as microliters of C_2H_4 per kilogram per hour.

Quality Measurements. External color measurement was performed by using a HunterLab colorimeter D25 (HunterLab D25-PC2-Hunter, Reston, VA); readings were taken on both sides of the equatorial part of the fruit.

Whole fruit firmness was monitored using a deformation test under nondestructive force (*1*). Fruits were placed widthwise over the plate of an Instron universal testing machine (model 4301, Instron, Canton, MA) and compressed with a flat compression anvil (55 mm in diameter) to a fixed load of 3 N, at a rate of 25 mm min^{-1} (chart speed = 10 mm min^{-1}). Data were expressed in terms of millimeters of deformation under a force of 3 N.

Titratable acidity (TA) was measured by titration of 2 g of puree diluted with 100 mL of water to pH 8.1 with 0.1 N NaOH, using three drops of phenolphthalein as colorimetric indicator. Results were expressed as a percentage of malic acid.

Juice SSC was detected with a model RL-2 table refractometer (Abbè, Officine Galileo, Florence, Italy) calibrated at 20 °C. Flesh of apricots was sliced, homogenized with an UltraTurrax, and centrifuged to extract the juice.

Enzyme Extraction and Assay. Mesocarp tissue (2 g) was homogenized in 4 mL of 50 mM sodium acetate extraction buffer (pH 6) containing 1.4 M NaCl, 0.2% (w/v) cysteine, and 1% (w/v) poly-(ethylene glycol) (PEG) (*16*). Homogenate was stirred for 2 h and then centrifuged at 17000 rpm for 30 min. Supernatant was desalted using an NAPTH 10 Sephadex G-25 column, which had been pre-equilibrated with the same buffer, 50 mM sodium acetate (pH 6). All of the above steps were carried out at 4 °C.

The assay mixture for glycosidase activities consisted of 50 μL of enzyme extract in 950 μL of corresponding *p*-nitrophenyl derivatives of specific substrate. Optimal pH, K_m, and V_m for each glycosidase were found to measure activities under ideal conditions. Final concentrations in 50 mM sodium acetate buffer were 15 mM for α-D-mannopyranoside (pH 4.6), 9.5 mM for α-D-glucopyranoside (pH 5.4), 16 mM for β-D-glucopyranoside (pH 5.4), 1.5 mM for α-D-galactopyranoside (pH 5), 10 mM for β-D-galactopyranoside (pH 4.4), and 10 mM for β-D-xylopyranoside (pH 4.4) (Sigma-Aldrich Co., St. Loius,

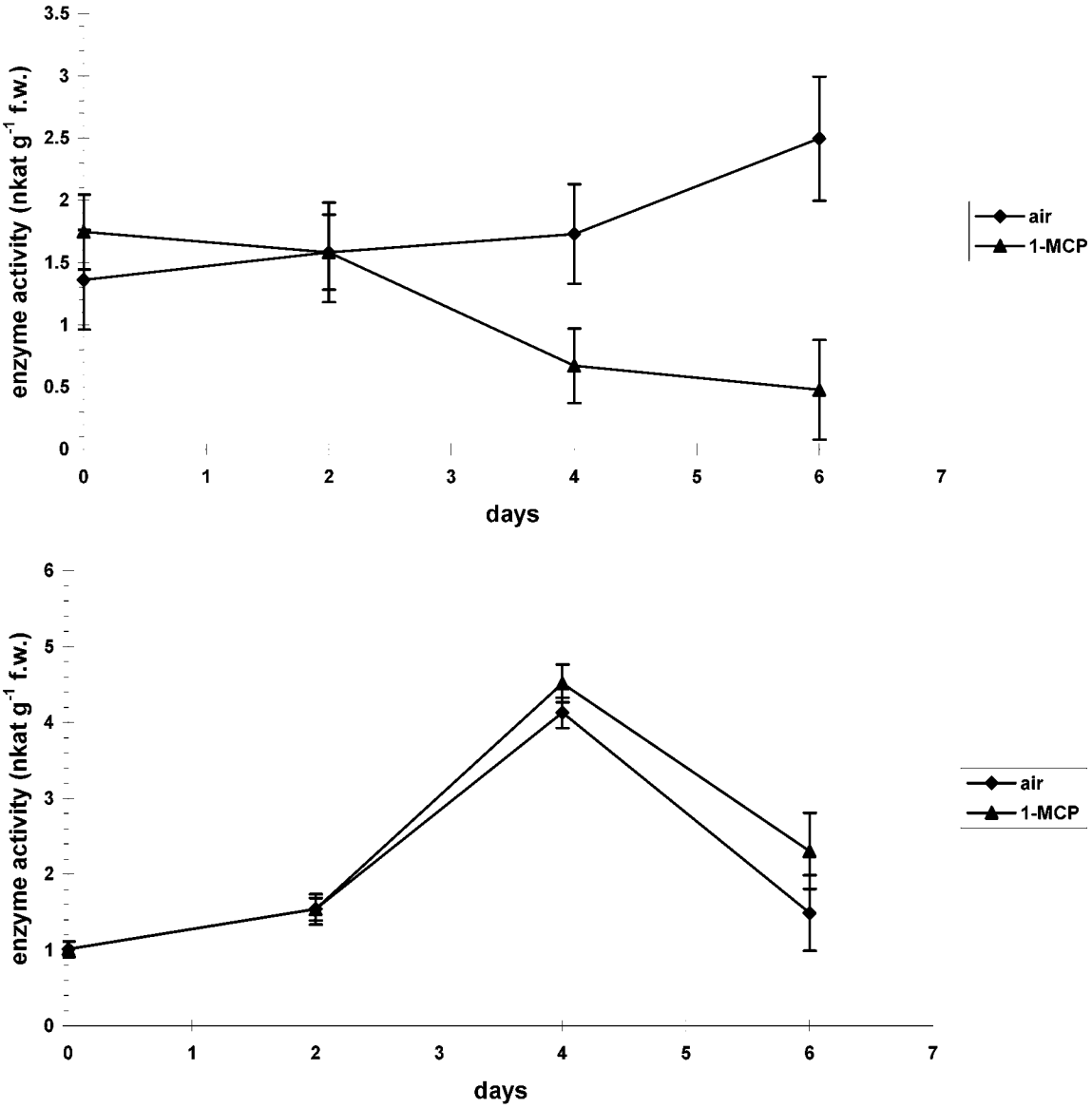

Figure 5. β-D-Galactosidase activity in cv. Ceccona (upper) and San Castrese (lower) apricots during ripening at 20 °C in air for 6 days. 1-MCP refers to apricots treated for 12 h with 1 μL L^{-1} in air at 20 °C. Data at each sampling time are the mean of three different apricots. Vertical bars represent SD.

MO). Results were presented as maximal activity after velocities had been calculated using the Michaelis−Menten equation.

The reaction mixture was incubated at 37 °C in a water bath for 60 min. Enzyme controls were incubated under the same conditions but with the enzyme solutions previously boiled for 10 min. To terminate the reaction, 5 mL of 0.1 M Na_2CO_3 was added and the formed *p*-nitrophenol was determined from the absorbance at 405 nm with a Lambda 3B UV−vis spectrophotometer (Perkin-Elmer Instruments Ltd., Seer Green, Beaconsfield, U.K.).

All glycosidase activities increased linearly for more than 1 h, with respect to substrate. Resulting values were expressed as nanomoles of *p*-nitrophenol formed per second (nkat) per gram of fresh weight.

PME was extracted by homogenizing 2 g of tissue with 4 mL of 1 M K_2HPO_4 (pH 7.5) for 1 h at 4 °C (17). Apricot extract (0.4 mL) was incubated with 0.6 mL of 0.75% (w/v) pectic solution (68% esterified) (Sigma-Aldrich Co.) in 1 mM phosphate buffer (pH 7.5) for 15 min at 37 °C. Transformation of alcohol in nitrite has been obtained by adding 2.5 mL of 7% (v/v) H_3PO_4 and 2.5 mL of 5% (w/v) KNO_2 and keeping the sealed vials in ice (*17*). After 15 min, 0.5 mL of headspace atmosphere was removed and analyzed by GC (Fractovap 4200, Carlo Erba Instruments) adapted with a 3 m long metal column of Chromosorb W 80/100 mesh and Ucon (LB 1715) nonpolar phase. Methanol (Carlo Erba SpA) was used as a standard.

Analysis of Volatiles. Five grams of apricot pulp was homogenized with 200 μL of standard solution (2-penten-3-one) and collected into a 25 mL glass miniflask (Supelco, Sigma-Aldrich Co., St. Louis, MO), sealed with a Teflon silicone septum. The sample was exposed to the fiber for 30 min in a water bath, Thermo Haake DL30-V15B (ENCO, Spinea-Ve, Italy) maintained at 20 ± 2 °C. The fiber, carbowax/divinylbenzene (CW/DVB, 65 μm) (Sigma-Aldrich Co.), was conditioned in a GC injection port at 250 °C for 2 h prior to use. Several preliminary tests were carried out to test the best fiber and the time of exposure for the analysis of apricot volatile compounds.

After the selected time of extraction, the SPME fiber was transferred to the injection port of the GC and thermally desorbed at 250 °C for 7 min. The splitless injector was mounted on a model 5300 Mega series gas chromatograph (Carlo Erba Instruments) equipped with a fused silica capillary column impregnated with a polar phase such as Carbowax 20M (Alltech Assosciates, Inc., Deerfield, IL), 60 m long, 0.25 mm i.d., and 0.25 μm film thickness. Helium was the carrier gas (27 cm s^{-1}); temperature was maintained at 40 °C for 7 min and then programmed to reach 230 °C at a rate of 3 °C min^{-1}, with a final isotherm of 30 min. A high-sensitivity FID at 260 °C was used. The signal was recorded and integrated by a Mega series integrator. Headspace volatile compounds of apricots were identified by means

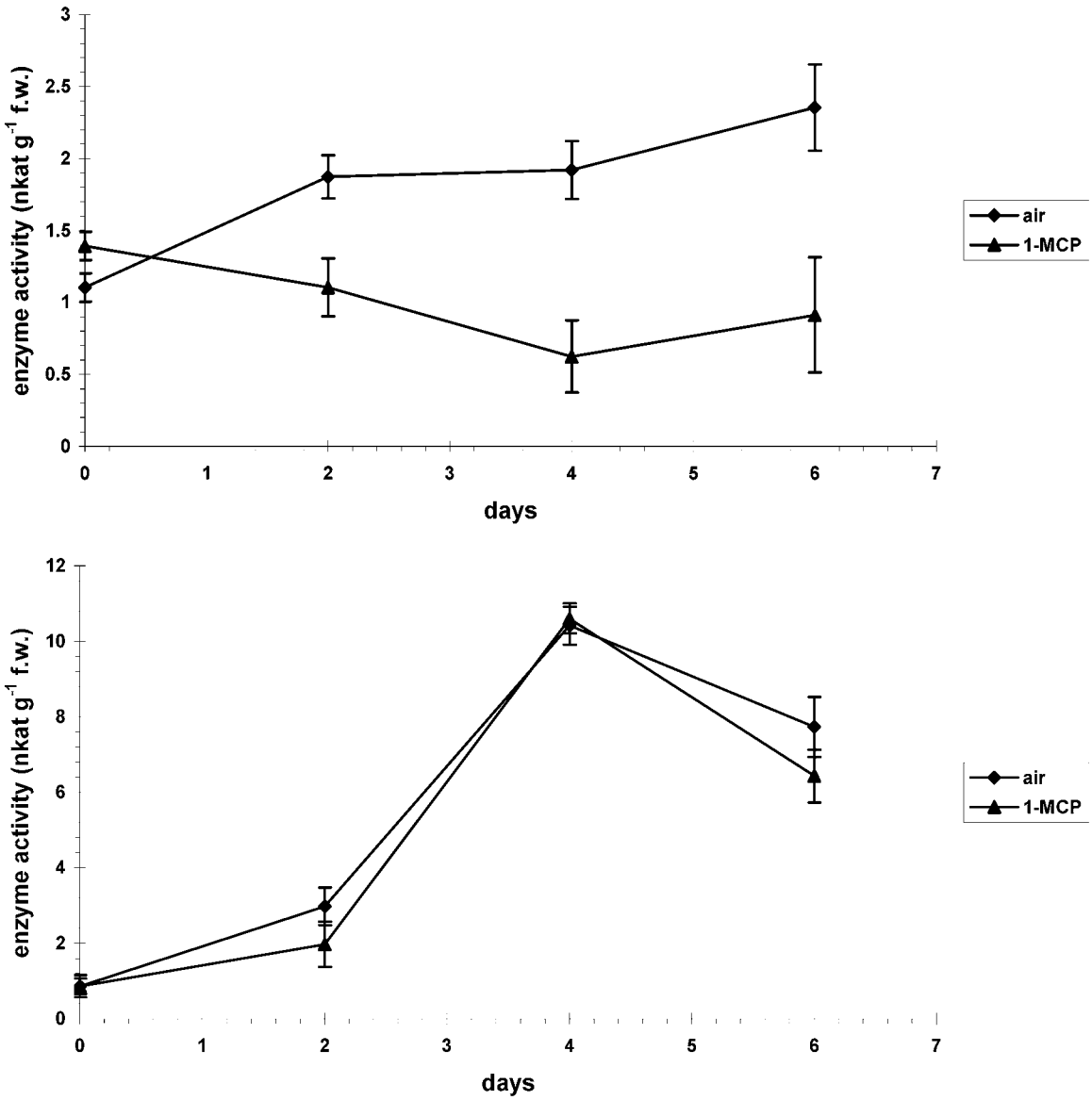

Figure 6. β-D-Xylosidase activity in cv. Ceccona (upper) and San Castrese (lower) apricots during ripening at 20 °C in air for 6 days. 1-MCP refers to apricots treated for 12 h with 1 μL L^{-1} in air at 20 °C. Data at each sampling time are the mean of three different apricots. Vertical bars represent SD.

of pure standard compounds and comparing retention indices of sample compounds and standards (Sigma-Aldrich Co.).

RESULTS AND DISCUSSION

At the beginning of postharvest ripening, ethylene production in air-treated San Castrese apricots was double that of Ceccona fruit production (**Figure 1)**. Subsequently, the rate of ethylene rose significantly after 72 h, starting from 8 μL kg^{-1} h^{-1} and reaching 30 μL kg^{-1} h^{-1} at the end of the experiment. In Ceccona, ethylene production began to rise slightly after 36 h and, after 72 h, increased at a higher rate than in San Castrese fruit, reaching a higher value at the end of the experiment. 1-MCP greatly inhibited ethylene production in both varieties, confirming what was observed by Fan et al. (*13*) in cv. Perfection apricots and by Dong et al. (*15*) in cv. Canino apricots.

Ceccona apricot deformation values were significantly higher than those of San Castrese apricots, and the rate of deformation increased much more in air-treated Ceccona fruit, from 0.65 to 3.15 mm, confirming this variety's extreme sensitivity to fruit softening (**Figure 2**). In San Castrese, deformation values of air-treated samples increased from 0.9 to 2.2 mm. 1-MCP treatment of Ceccona apricots significantly reduced the deformation values from day 2, whereas in San Castrese, the effect on softening reduction was significant only from day 4. Although 1-MCP treatment reduced ethylene production in both varieties, fruit deformation increased anyway, even though at different rates in the two varieties. In cv. Moniqui apricots, Chahine (*3*) reported that softening begins when ethylene is almost undetectable, and Mbeguiè-a-Mbeguiè et al. (*18*) showed that 1-amino-1-cyclopropanecarboxylic acid (ACC) oxidase (ACO) is expressed at this stage. In ACO antisense melon, where ethylene production is inhibited by 95%, softening occurs presuming an ethylene-independent factor involved in the loss of firmness (*19*, *20*). Gene coding for cell wall enzymes (polygalacturonase) was found to be responsive to very low levels of ethylene (*21*), and ripening-related α-arabinosidase showed a low level of activity in ethylene-deficient tomatoes (*22*); ripening-related β-gal transcripts were detected as well, even at low level, in immature green tomatoes, where only basal ethylene was produced (*23*). Nanos et al. (*4*) showed that propylene stimulated ethylene production in apricots kept at 25

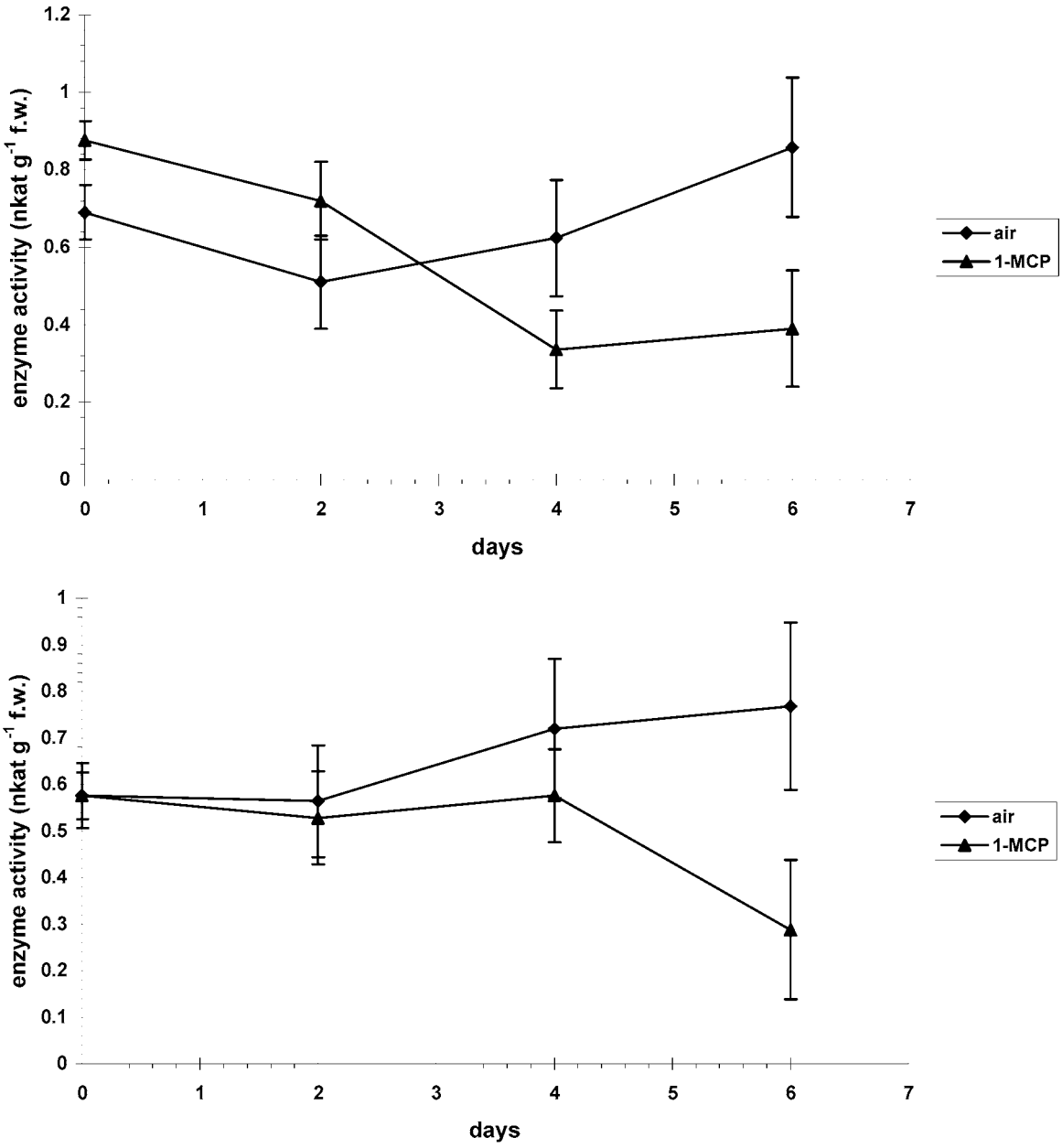

Figure 7. α-D-Mannosidase activity in cv. Ceccona (upper) and San Castrese (lower) apricots during ripening at 20 °C in air for 6 days. 1-MCP refers to apricots treated for 12 h with 1 μL L^{-1} in air at 20 °C. Data at each sampling time are the mean of three different apricots. Vertical bars represent SD.

°C, and this autocatalytic effect was observed to increase softening by stimulating the activity of some glycosidases and PME (*10*). It is likely that the cell wall degradation system of apricots is very sensitive to ethylene even at the basal level. In addition, nonenzymatic deaggregation/degradation was postulated for the solubilization and depolymerization of wall polysaccharides due to the action of •OH radical formation (*24*).

In Ceccona apricots, PME activity decreased during postharvest ripening without a significant difference between treatments except on day 3, when the activity was lower in apricots treated with 1-MCP (**Figure 3**). In air-treated San Castrese apricots, PME activity rose slightly on day 3 and subsequently decreased, whereas in apricots treated with 1-MCP, the activity did not change. In a previous paper (*10*), we observed the same declining pattern of PME activity with progressive postharvest ripening, a decline delayed by propylene treatment. This pattern was reported in melon, banana, and peach also (*19*, *25*, *26*). In avocado, the declining pattern was delayed by 1-MCP treatment, although polygalacturonase and cellulase activities were reduced (*27*). In our case, 1-MCP reduced the activities of PME, but untreated apricots showed different behaviors between the two varieties. This response could be due to the varieties as well as the ripening stage; indeed, here the pattern of activity of untreated fruit is slightly decreasing but not as rapid as that observed by Cardarelli et al. (*10*) in cv. Boccuccia Spinosa apricots.

In air-treated Ceccona fruit, α-gal and β-gal showed a slight increasing pattern, whereas the activities in apricots treated with 1-MCP were significantly reduced (**Figure 4**). In San Castrese apricots, no significant differences in activity were observed between the treatments for both enzymes, but α-gal activity progressively decreased (**Figure 4**), whereas β-gal showed a peak on day 4 and subsequently declined (**Figure 5**).

In air-treated Ceccona fruit, xyl activity increased and 1-MCP treatment significantly reduced the activity, as observed for the galactosidases (**Figure 6**). The pattern of activity in San Castrese

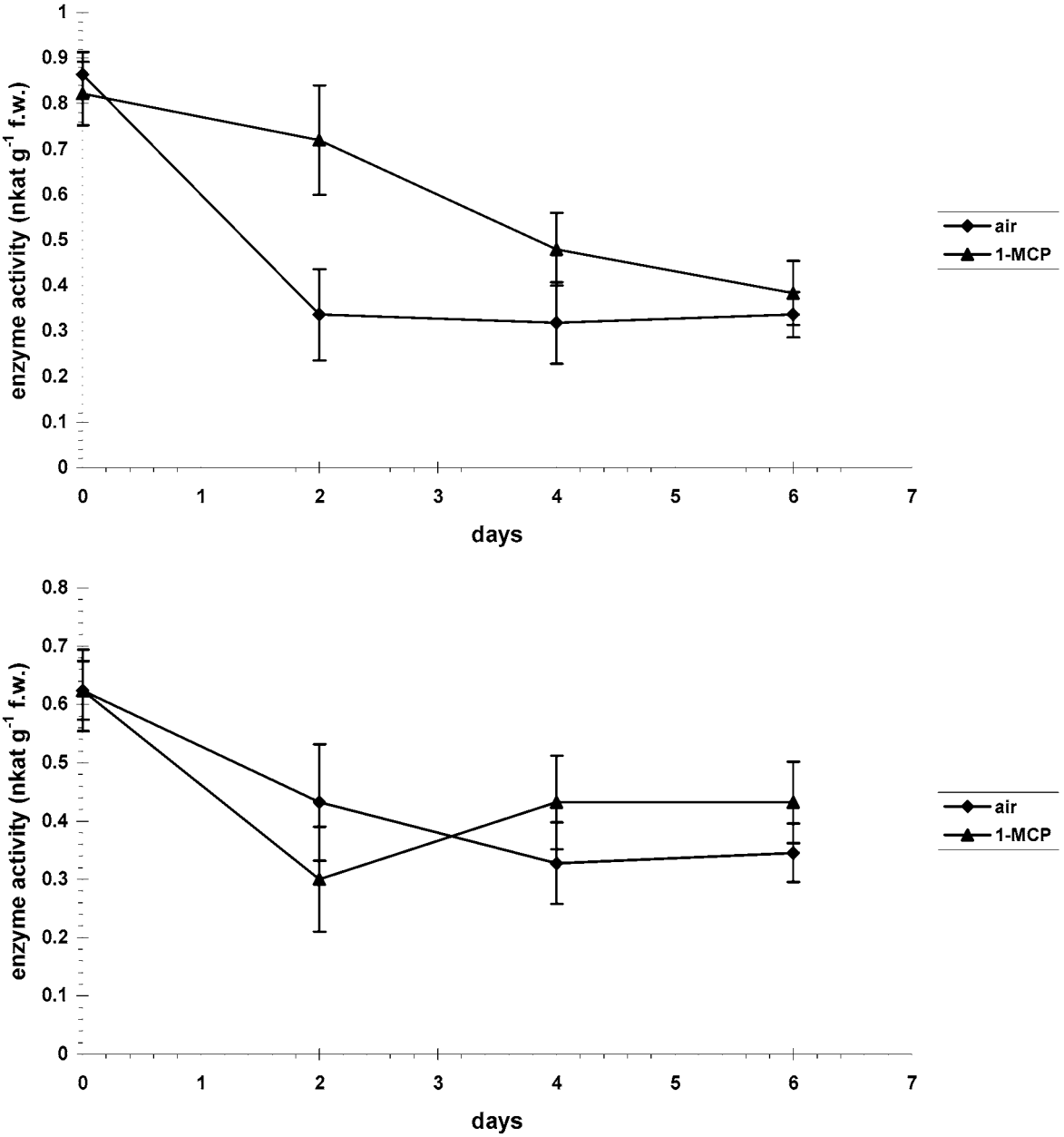

Figure 8. α-D-Glucosidase activity in cv. Ceccona (upper) and San Castrese (lower) apricots during ripening at 20 °C in air for 6 days. 1-MCP refers to apricots treated for 12 h with 1 μL L^{-1} in air at 20 °C. Data at each sampling time are the mean of three different apricots. Vertical bars represent SD.

fruit was similar to that of β-gal, with the peak on day 4, without significant difference between treatments. The value of activity in San Castrese was much higher than in Ceccona, and this might be related to variety and/or ripening stage. The same increasing pattern was observed in apricot cv. Boccuccia Spinosa, even though with lower values of activity (**10**).

α-Man activity in air-treated apricots of both varieties did not change significantly but showed a rising pattern; 1-MCP treatment decreased the activity in both varieties (**Figure 7**).

Even α-glu activity decreased in air-treated apricots in both varieties (**Figure 8**); 1-MCP treatment maintained higher activity in Ceccona fruit but not in San Castrese. In contrast, β-glu activity showed a peak on day 4 in air-treated Ceccona apricots, whereas the activity was almost constant in San Castrese (**Figure 9**). 1-MCP treatment inhibited the activity increase in Ceccona or decreased the activity in San Castrese, but at the end of the experiment, the difference between the treatments was not significant.

Propylene treatment in apricots strongly increased glycosidase activity, mainly β-D-xylosidase, β-D-galactosidase, α-D-mannosidase, and α-L-arabinofuranosidase, in parallel with the increase of ethylene production and softening (*10*). β-D-Galactosidase and α-D-galactosidase activities in ethylene-suppressed tomatoes (antisense ACC synthase) increased when the tomatoes were treated with ethylene, along with softening (*28*), as well as in ethylene-suppressed melons (antisense ACC oxidase) (*19*).

In Ceccona apricots, 1-MCP shows an inhibitory effect on α-gal and β-gal, xyl, α-man, and β-glu activities, while maintaining higher α-glu activity. In San Castrese, β-gal and xyl showed significantly increasing activity with values higher than in Ceccona; 1-MCP had no effect except on α-man activity and a slight effect on β-glu activity. Galactose and arabinose release appears to be a ubiquitous feature of ethylene-regulated fruit ripening, and xylose is the main neutral monosaccharide lost from the cell wall of apricots (*29*). The different response

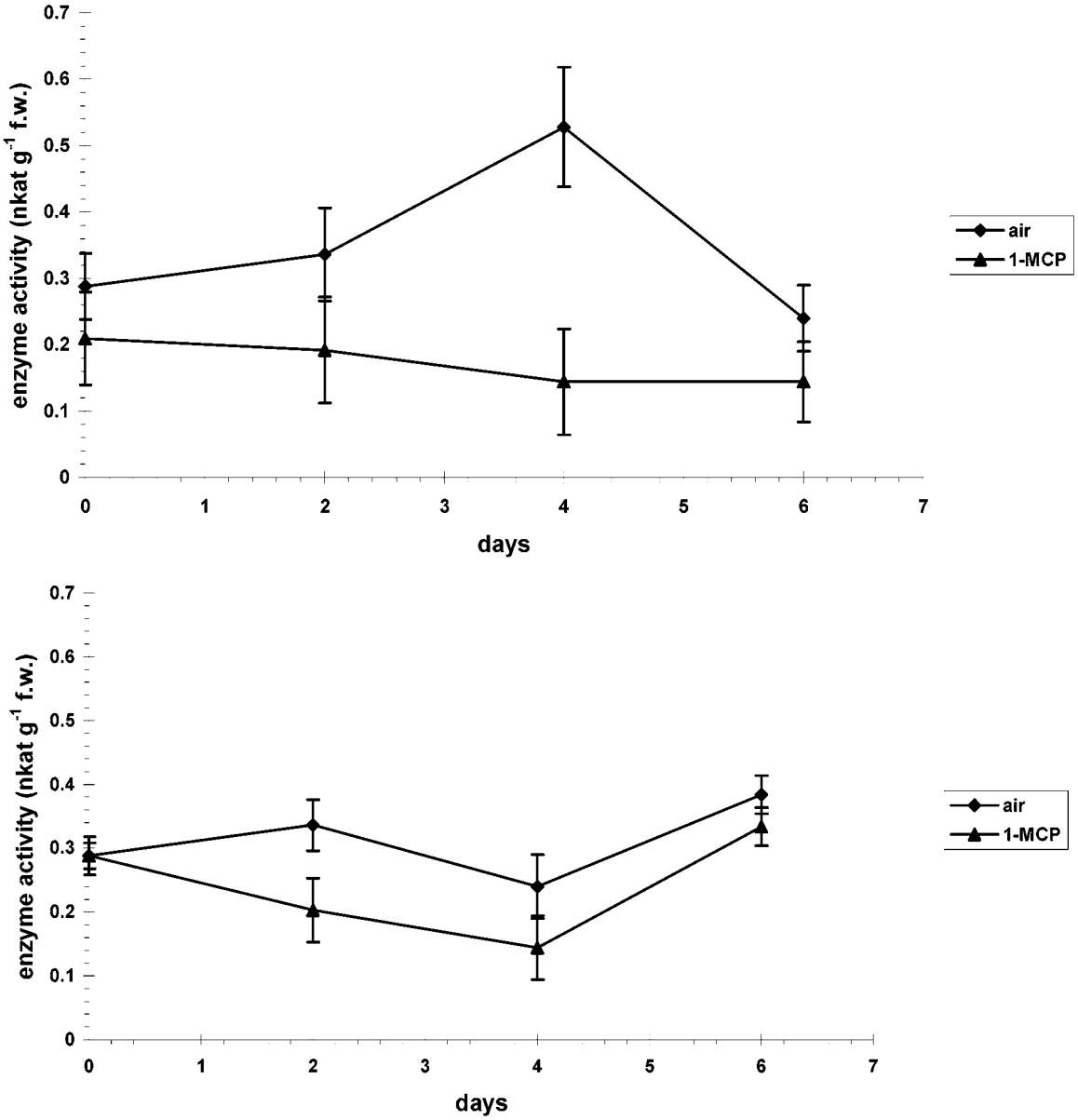

Figure 9. β-D-Glucosidase activity in cv. Ceccona (upper) and San Castrese (lower) apricots during ripening at 20 °C in air for 6 days. 1-MCP refers to apricots treated for 12 h with 1 μL L^{-1} in air at 20 °C. Data at each sampling time are the mean of three different apricots. Vertical bars represent SD.

of the glycosidases' activity to the 1-MCP treatment between the two varieties is related to the different rate of softening (deformation values). Indeed, as observed, the difference in deformation between 1-MCP-treated and untreated San Castrese apricots is low, whereas in Ceccona, the difference is greater. Dong et al. (*15*) reported in Canino apricots that the failure of 1-MCP to inhibit softening of fruit treated before storage was related to ethylene production, which was high enough to trigger the softening of treated fruit. San Castrese apricots, at harvest, are already in an advanced climacteric stage, and ethylene production is double the ethylene production of Ceccona apricots. Although 1-MCP inhibits ethylene production in San Castrese apricots, it is likely that the initial level of the hormone is high enough to stimulate softening and to overcome the inhibitory effect of 1-MCP on most glycosidases. Thus, the general feature of the beginning of apricot softening when ethylene is not yet increasing and the slight difference in deformation between 1-MCP-treated and untreated San Castrese apricots would confirm that other cell wall enzymes are strongly involved, starting from PME, the activity of which was reduced by 1-MCP. Moreover, the possibility that different isoenzymes may contribute to the composite, total activity of glycosidases must be considered. As for polygalacturonase (*30*), one isoform could work with a low ethylene level and/or not be affected by a rise in ethylene; in addition, another isoform, targeting a different natural substrate, could produce significant physiological and textural change.

With regard to the quality parameters, we did not observe significant differences between control and 1-MCP-treated apricots. Acidity was higher in San Castrese apricots than in Ceccona and decreased in both varieties, but significantly in fruit of the former variety (**Table 1**). SSC did not change significantly in either variety, with no difference between treated and untreated fruits, confirming that sugar and acid metabolisms in apricots are ethylene independent (*3*, *10*). Even the color of apricot fruit was not significantly affected by ethylene inhibition, as observed in relatively ripe apricots treated with 1-MCP (*13*) or in Canino apricots after ripening, before or after storage (*15*).

The volatile compound content in Ceccona fruit was much higher than in San Castrese. Both varieties were characterized

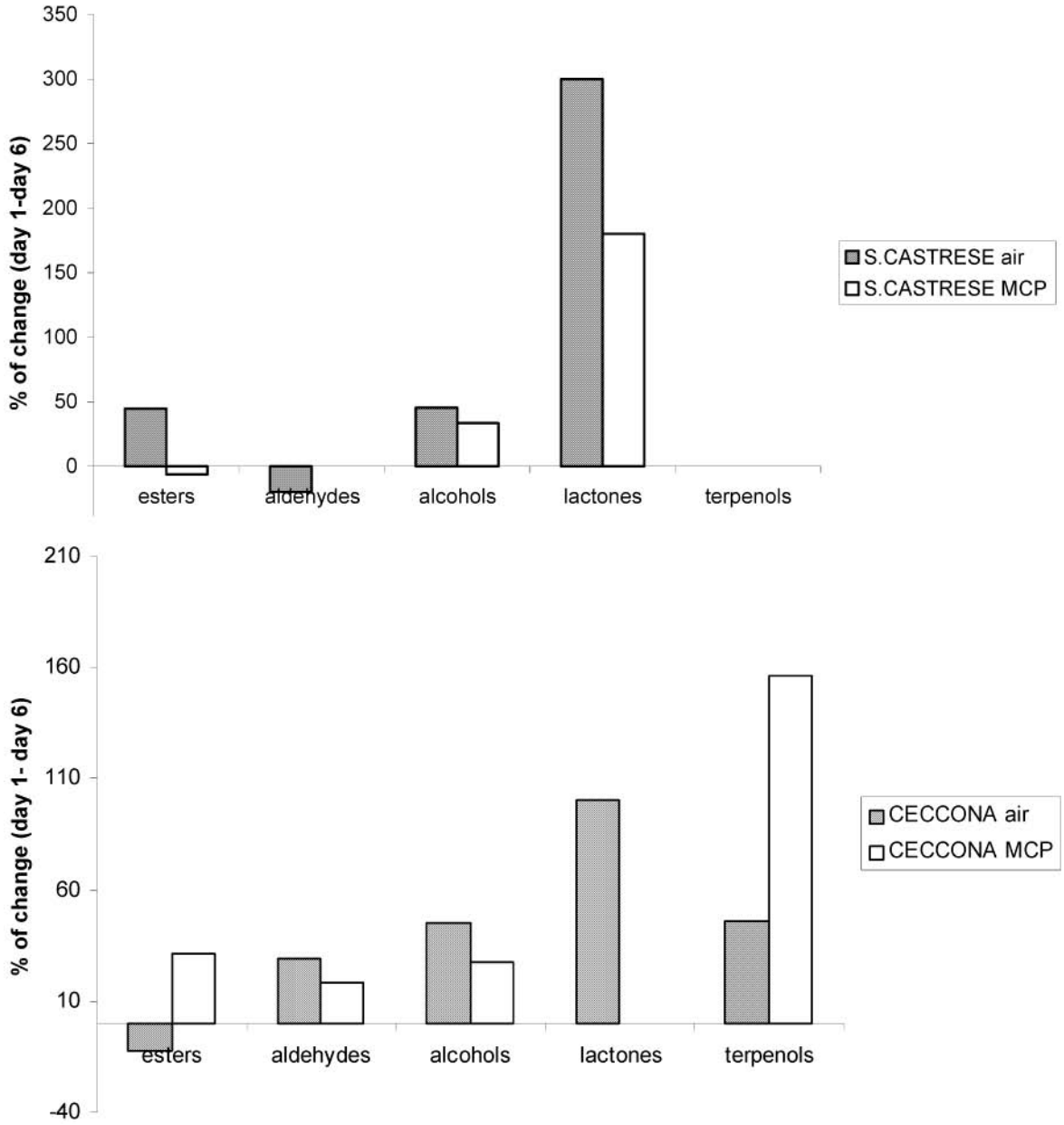

Figure 10. Percentage of change of volatile groups between the first and the sixth day of ripening at 20 °C of cv. Ceccona and San Castrese apricots. MCP refers to apricots treated for 12 h with 1 μL L^{-1} 1-MCP in air at 20 °C. Data are the mean of three readings on each day.

by a high ester content (hexyl acetate, *trans*-hex-3-enyl acetate, *cis*-hex-2-enyl acetate, and ethyl acetate). In Ceccona, the ester content was double that of San Castrese apricots. Ceccona apricots had a higher aldehyde content (mainly *cis*-hex-2-enal, hexanal, nonanal, benzaldehyde, and pentanal), and a 3−4-fold higher alcohol content (mainly ethanol, hexanol, *cis*-hex-3-enol, *cis*-hex-2-enol, butanol, and linalool) than San Castrese apricots. Lactones (γ-octalactone and hexalactone), even though at a very low level, were double in Ceccona. In **Figure 10** we can observe the percentage of increase or decrease of the main volatile groups between days 1 and 6. In untreated Ceccona fruit, all volatile groups except esters increased during postharvest ripening, with the highest increase for lactones. 1-MCP inhibited this increase but stimulated the rise in terpene alcohols (linalool and terpenol), even though the concentration of these compounds was very low. This increase might be related to the higher α-glu activity; indeed, the relationship between glycosidases, α-glucosidase above all, and the release of glycosidically bound terpenes in apricots is known (*31*). In San Castrese untreated apricots, lactones greatly increased during postharvest ripening to a greater extent than in 1-MCP-treated apricots. Esters rose in air-treated fruit, whereas a slight decrease was observed in 1-MCP-treated apricots. In contrast, aldehydes decreased in untreated apricots.

These results confirm what was observed by Fan et al. (*13*) with regard to the inhibition of 1-MCP on apricot ripening and on aroma (mainly esters and alcohols) development. This effect of 1-MCP was observed in peach, where aroma development was stimulated by propylene and inhibited by 1-MCP, consistent with the stimulation or inhibition of ethylene synthesis (*32*, *33*) in apple and banana, where 1-MCP treatment maintained higher levels of aldehydes and alcohols, reducing ester formation (*34*, *35*). Ceccona apricots were more aromatic than San Castrese apricots, and the difference was easily detectable during the subjective sensory evaluation carried out in the laboratory during the analysis of the volatiles. In Ceccona, 1-MCP treatment slightly reduced the total production of volatiles but greatly

Table 1. Changes of Qualitative Parameters, Titratable Acidity as Percent Citric Acid, Refractometric Index (SSC %), and Color (*a* and *b*) on Day 0 and at the End of the Test, Day 6

quality		cv. Ceccona		cv. San Castrese	
parmeter	sample	day 0	day 6	day 0	day 6
acidity	air	1.40 ± 0.11	1.15 ± 0.19	1.99 ± 0.17	1.55 ± 0.15
	MCP	1.41 ± 0.17	1.05 ± 0.14	1.99 ± 0.15	1.54 ± 0.13
SSC (%)	air	11.1 ± 0.9	11.8 ± 1.1	15.2 ± 1.3	14.6 ± 1.3
	MCP	0.8 ± 1.0	11.5 ± 1.3	15.2 ± 1.4	14.1 ± 1.3
color *a*	air	12.3 ± 1.5	12.6 ± 1.7	11.7 ± 2.0	15.1 ± 2.5
	MCP	11.2 ± 1.7	14.0 ± 2.0	12.7 ± 2.8	15.2 ± 3.0
color *b*	air	26.4 ± 2.4	25.1 ± 2.4	26.7 ± 2.5	23.7 ± 2.0
	MCP	27.5 ± 2.3	25.7 ± 2.4	26.7 ± 2.6	24.6 ± 2.1

[a] Data are the means of 10 readings for acidity and SSC ± SD. For the color results, the values refer to the same fruit used for deformation measurements (performed nondestructively by Instron) and thus are the same used for all tests.

modified the aroma profile, affecting the formation of lactones and terpenols.

CONCLUSIONS

Apricots must be picked at a ripening stage as near as possible to the optimum edible quality in order to have good aroma development, especially for low-aroma varieties such as San Castrese. 1-MCP, which significantly inhibits ethylene production, can help to maintain firmness, but apricots lose aroma, even though slightly and not easily detectable at the sensory evaluation. Ceccona fruit, which is more aromatic, could be harvested at an early ripening stage; the treatment with 1-MCP greatly inhibits ethylene production and controls loss of firmness but modifies the aroma profile. In this variety, picked at an early stage of ripening when ethylene was very low, glycosidase activity was strongly reduced by 1-MCP, and this might have played an important role in the modification of the aroma.

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