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PEACH ANTIOXIDANT AND PHENOLIC ACTIVITIES INFLUENCED BY THE APPLICATION OF 1-METHYLCYCLOPROPENE (1-MCP) AT POST-HARVEST

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ABSTRACT

Early maturing peach (*Prunus persica*) cultivars can fetch good market value but face a lot of post-harvest problems that lead to the post-harvest losses. The 1-methylcyclopropene (1-MCP) can provide new insights into plant ethylene responses and extend the shelf life and quality of fruits. Therefore, fruits of peach cultivar 'Early Grand' were dipped in various concentrations of 1-MCP (0, 0.3, 0.6 and 0.9 µg l^{-1}), stored for 40 days at 8 ±2°C with 50% relative humidity and analyzed the fruits for physicochemical attributes at 10 days interval. The highest concentration of 1-MCP at 0.9 µg l^{-1} significantly improved the activity of antioxidants, catalase, free radical scavenging assay and total phenols. However, the peach fruits treated with 1-MCP at 0.6 µgL^{-1} was effective in retaining the ascorbic acid, lowering the weight loss and fruit decay. Therefore, peach fruits can be treated with 1-MCP (0.6 µg l^{-1}) solution for prolonging its shelf life up to 40 days under low temperature.

Key words: biochemical attributes, catalase activity, fruit decay, shelf life, antioxidant and phenolic activities, 1-methylcyclopropene, *Prunus persica*

INTRODUCTION

Physiology and biochemistry of fruits are considerably tainted during the ripening process. During this process, the natural changes occur in the fruits and later become ready for the consumer to eat. Some of changes occuring in the fruit are the alteration in texture, color modification, changes in the amount of sugars, organic acids and other volatile compounds, which affects the flavor, aroma and nutritional quality [Giovannoni 2004]. These developmental changes take place in both climacteric and non-climacteric fruits. The changes in both types of fruits are different, which is due to the response to respiration and ethylene production [Barry and Giovannoni 2007].

Peach (*Prunus persica*), being climacteric in nature, passes through increased rates of biological activities like respiration and ethylene production [Lelievre et al. 1997], which changes the chemical composition and physical attributes of the fruit [Trainotti et al. 2006]. All these changes ultimately result in ripening and senescence process [Lelievre et al. 1997]. These chang-

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es lead to increased respiration rate, ethylene production, aroma development, color, texture, organic acids, aromatic and volatile substances [Remorini et al. 2008]. Peach fruits after ripening are exposed to physical damage, which results in short post-harvest life with the loss of quality. All these factors result in the variation of textural firmness, skin color, sugar content and phenolic compounds [Cascales et al. 2005]. During the post-harvest, oxidation process produces free radicals that increase the electrolytic leakage and lead to the destruction of tissues. Fruits antioxidants are involved in neutralizing the damaging ability of free radicals [Abbasi and Kushad 2006]. It has been estimated that there are about 17–40% losses in horticultural crops [Rind 2003].

Due to the perishable nature, less attention has been paid to the production of the peach fruit crop. This is because of its perishability and short post-harvest life during the storage [Khan et al. 2016], usually 3–4 days when kept at ambient temperature [Wills et al. 2007]. The post-harvest losses in peach are about 23% [Khan 2012]. The major factor that reduces the post-harvest life of peach fruits is high temperature and low relative humidity during harvesting and marketing [Tonini and Tura 1998]. During the ripening process, peach fruit exhibits a rise in ethylene production due to increased respiratory activities [Brovelli et al. 1998].

A large number of biological and chemical practices is used to slow down the respiratory rate and ethylene production, which extends the shelf life of peach fruit throughout the world. Among these techniques, the post-harvest application of 1-methylcyclopropene (1-MCP) has been added to the list of options that slow down the rate of respiration and ethylene production to extend the shelf life and quality of plant products [Blankenship and Dole 2003]. Recent studies indicated that exposure of fruit to ethylene prior to 1-MCP application resulted in a moderated effect on fruit ripening with delayed ripening process [Zhang et al. 2010]. Like other horticultural plants, stone fruits have also been tested with a wide range of 1-MCP concentrations and it was reported that 1-MCP was effective in reducing the synthesis of many cell wall degrading enzymes (polygalacturonase, galactosidase, and endo-glucanase/glucosidase), leading to a delay in fruit softening [Manganaris et al. 2007].

Keeping in view the perishability of peach, its short post-harvest life and effectiveness of 1-MCP in slowing down the rate of respiration, ethylene production and reducing post-harvest losses with retaining the quality attributes in peach, the present experiment was designed with the objectives to find out the optimum concentration of 1-MCP to retain the enzymatic activities and biochemical attributes of peach fruit during storage.

MATERIAL AND METHODS

Plant material and procedure

To improve the storability, a research was planned to study the antioxidant and phenolic activities of peach (*Prunus persica*) as influenced by the post-harvest application of 1-methylcyclopropene (1-MCP) in 2015 at Post Harvest Laboratory, Agricultural Research Institute (ARI) Tarnab with The University of Agriculture Peshawar, Pakistan. The peach fruits cv. 'Early Grand' of uniform size and maturity, were brought from Peach Orchard at ARI Tarnab, Peshawar with Horticultural Research Farm, The University of Agriculture Peshawar. Peach fruits were sorted for experimental purpose and discarded over or under-ripened, bruised and damaged fruits. The fruits were then washed with tap water to remove any residual material or dust from the surface of selected fruits, air dried. Fruits were dipped in different concentrations of 1-MCP (0, 0.3, 0.6 and 0.9 µg l^{-1}) for 5 min [Argenta et al. 2007] and then properly placed according to completely randomized design (CRD) with three repeats, which were stored for 40 days at 8 ±2°C with 50% relative humidity (RH) and analyzed the fruit samples for various biochemical attributes with 10 days of interval.

Attributes measurement

To study the effect of 1-MCP on the post-harvest life of peach, the following various physicochemical attributes were recorded.

Antioxidant activity of the fruit (mg kg^{-1}). Analysis of antioxidant activity for fruit pulp of peach was carried out by the method of DPPH (2,2-diphenyl-1-

-picrylhydrazyl) [Zhang et al. 2015]. Five randomly taken fruits from each treatment in each replication were taken and peeled with a knife. The pulp was collected and stored in separate bags at –80°C in the refrigerator until analyzed. The sample bags were taken out and left for 10 min at room temperature just before the extraction. Then 10 g of fruit pulp was taken separately from each sample bag and mixed with 50 ml of 50% methanol and then homogenized for 30 s. All sample solutions were centrifuged at 15,000 rpm for 15 min and the supernatants were collected for the analysis of antioxidant activity. Finally, all samples were analyzed using spectrophotometers against blank sample and absorbance was reached at 517 nm.

Catalase activity (unit g^{-1} protein). For determination of catalase activity of peach, fruit was ascertained by the method as described by Abbasi et al. [1998]. To accomplish the reaction of buffer solutions, buffer A was prepared by adding 2.9 ml, 15 M K_2HPO_4 buffer at pH 7.0 in a cuvette as the other solution of buffer B was made by adding 2.9 ml of 12.5 mM H_2O_2 in 15 M K_2HPO_4 buffer (pH 7.0) in another cuvette. Two cuvettes were separately filled with 100 µl of enzyme extract. Further, the two cuvettes were placed in a gloomy box. The optical densities at 240 nm of these cuvettes were noted at 45 and 60 s and this time was noted when the cuvettes were added with extract. The optical density difference at 45 and 60 s intervals was recorded using a spectrophotometer of Optima® 3000 plus and the readings were used to compute the catalase activity. The results were expressed as catalase unit g^{-1} protein.

DPPH free radical scavenging assay (%). DPPH free radical scavenging assay was determined using the method described by Jain et al. [2008]. Using methanol as a blank sample, the spectrophotometer was blanked at the beginning of the analysis. Then 0.5 ml of peach extract was taken and each one was added to 2 ml DPPH solution (0.2 mM concentration of methanol). Then they were incubated at room temperature for 30 min. Finally, all samples were analyzed using spectrophotometers against blank sample and absorbance was reached at 517 nm.

Radical scavenging activity (RSA) or inhibition of free radicals (1 %) by DPPH of the treatment extracts were calculated using the following formula:

$$1\,\% = \frac{\text{Absorbance of the blank (A)} - \text{Absorbance of the treated sample (B)}}{\text{Absorbance of the blank (A)}} \times 100$$

Total phenolics content (mg of GAE per 100 g of dry matter). Peach fruit juice was used to determine the total phenolics content with Folin Ciocalteu reagent according to Piga et al. [2003]. Each composite sample (5 g) from five different peach fruits per replication of each treatment was homogenized. The same was subjected to centrifuge at 4,000 × g for 15 min followed by filtration. A sample of 1 ml from the same extract, 5 ml Folin-Ciocalteu reagent, 10 ml of 7% Na_2CO_3 solution and distilled water was added after one-hour incubation, the absorbance was recorded against the blank containing reagent at 760 nm. All treatments were replicated three times, thus conducted three times. Gallic acid standard solution was used to draw a standard curve for total phenolics content. For standard calibration, gallic acid solution (0–100 mg/l) was employed and run as per above procedure. The results were expressed in mg of gallic acid equivalents (GAE) per 100 g of dry matter and were computed using following formula:

$$C = cV/m$$

where:
C – total content of phenolics compound mg per g plant extract in GAE,
c – concentration of gallic acid established from the calibration curve (mg/ml),
V – the volume of extract (ml),
m – the weight of fruit pulp (g).

Ascorbic acid (mg 100 g^{-1}). Percentage of ascorbic acid was determined by the Titration method (redox titration) as described in AOAC [1990]. Fifty mg of 2,6 dichloroindophenol dye and 42 mg of sodium bicarbonate ($NaHCO_3$) were taken in 200 ml beaker and dissolved in hot distilled water. The beaker was stirred for 30 min and the volume was made up to

250 ml in a volumetric flask. Oxalic acid (0.4 g) was dissolved in distilled water and volume was made up to 100 ml. For making 1 L of 0.4% oxalic solution, 4 g was taken and dissolved in distilled water and the volume was made up to 1000 ml. Ascorbic acid (50 mg) was dissolved in 50 ml of 0.4% oxalic acid, then 2 ml of that solution was taken in a conical flask and dye solution was titrated against it till pink color persisted for 15 s. The dye factor was calculated with the help of the following formula.

$$\text{Dye factor (F)} = \frac{\text{ml of ascorbic acid solution}}{\text{ml of dye solution used}}$$

This dye factor was used in the ascorbic acid content formula later on. Peach fruit juice (10 ml) was taken and diluted in 0.4% oxalic acid solution, and the volume was made up to 100 ml. 10 ml of this diluted sample was taken in a conical flask and titrated against the dye until the appearance of light pink color that persisted for 15 s. The formula used for the ascorbic acid content is as follows:

$$\text{Ascorbic acid content } \left(\frac{\text{mg}}{100}\text{g}\right) = \frac{\text{F} \times \text{T} \times 100}{\text{D} \times \text{S}} \times 100$$

where:
F – dye factor,
T – ml of dye solution used from the burette,
D – ml of diluted sample taken for titration,
S – g of peach juice taken for dilution.

Weight loss (%). For determining the physiological loss in weight, six freshly harvested fruits were weighed and numbered before imposing the treatments at 0 days. Weight loss was calculated after 10, 20 and 30 days, which served as the final weight loss. The physiological loss in weight was determined by the following formula and expressed as a percentage.

$$\text{Fruit weightloss (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

Fruit decay (%). The fruit decay in each treatment and replication s visually examined on the daily basis and data were recorded in percentage for the fruits that were showing the symptoms of fruit decay for all treatment with the help of the following formula:

$$\text{Percent fruit decay} = \frac{\text{No. of decayed fruits}}{\text{Total number of stored fruits}} \times 100$$

Statistical analysis

The data recorded were arranged according to completely randomized design and were subjected to analysis of variance technique [Jan et al. 2009]. They were then analyzed using statistical software Statistix-8.1 [Statistix-8 Analytical Software 2003]. In case the data was found significant, least significant difference (LSD) test was applied for means comparison and separation.

RESULTS

Total antioxidant activity (mg kg^{-1}). Results revealed that 1-MCP storage duration and their interactions significantly influenced the antioxidant activity of peach (Tab. 1). Regarding means for 1-MCP concen-

Table 1. Analysis of variance of all the studied attributes of peach

Source of variation	DF	MS					
		WL	FD	FRSA	CA	TP	TAC
1-MCP concentrations (M)	3	0.59***	0.59***	2.66***	2.47***	2.34***	2.34***
Storage durations (SD)	4	184.50***	238.34***	114.84**	250.02***	235.41***	231.29***
M × SD	12	0.07***	0.07***	0.29**	0.35**	0.48***	0.48***
Error	40	0.01	0.01	0.11	0.12	0.11	0.11

WL – weight loss, FD – fruit decay, FRSA – free radical scavenging assay, CA – catalase activity, TP – total phenols, TAC – total antioxidant activity, *, **, *** significant at $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$, respectively

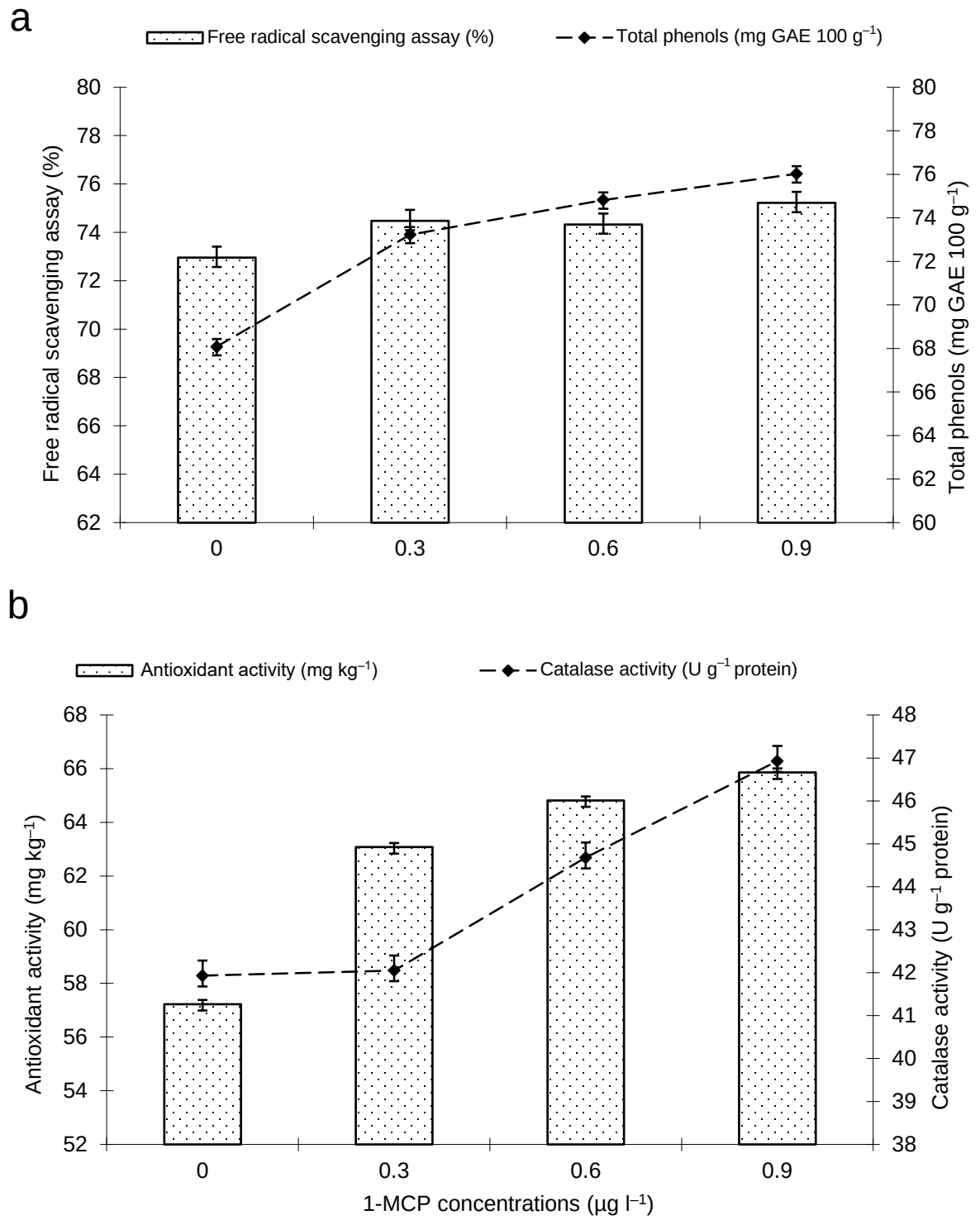

Fig. 1. (a) Free radical scavenging assay and total phenols, (b) antioxidant activity and catalase activity of peach fruits as affected by 1-MCP concentrations

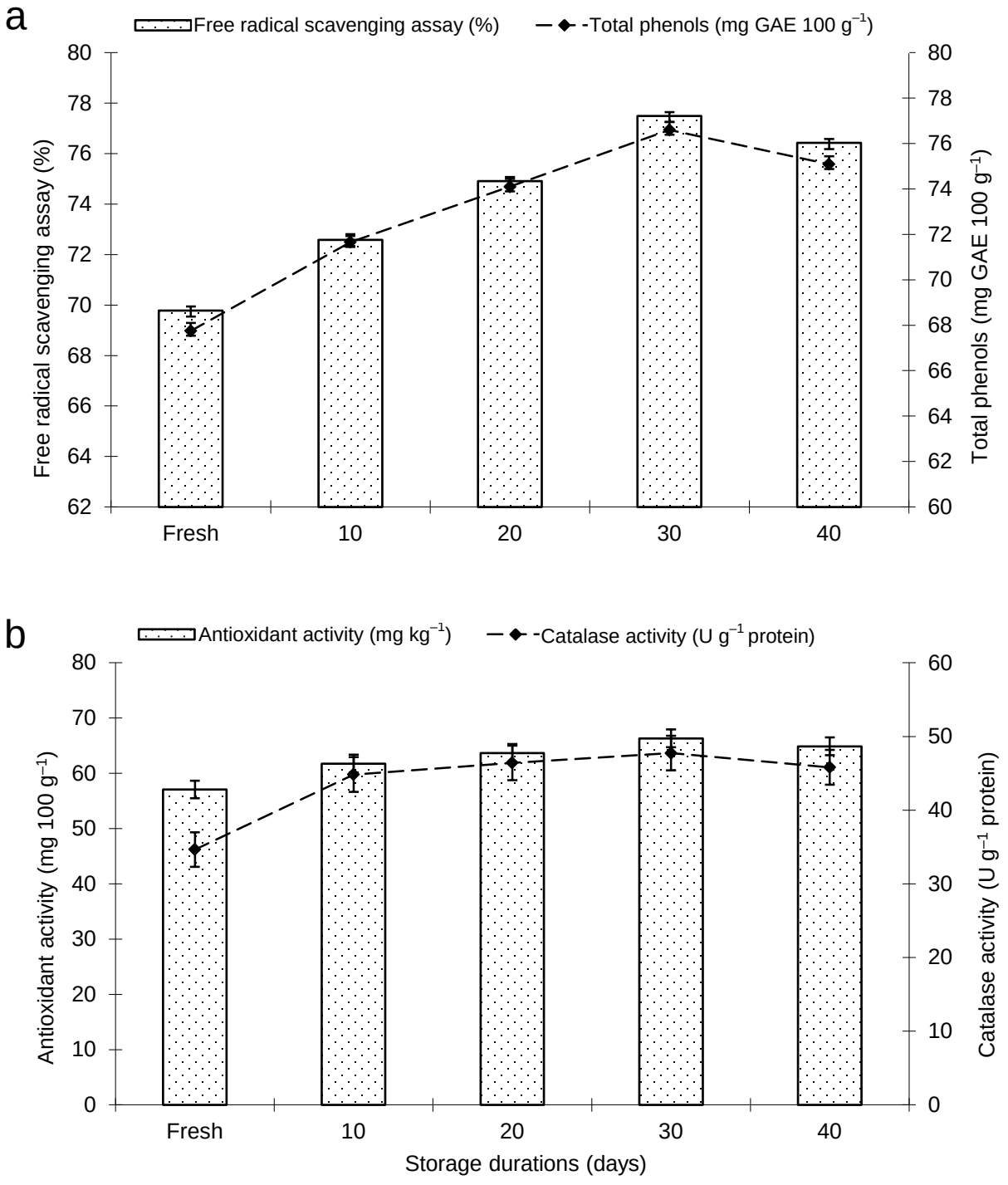

Fig. 2. (a) Free radical scavenging assay, total phenols, (b) antioxidant activity and catalase activity of peach fruits as affected by storage durations

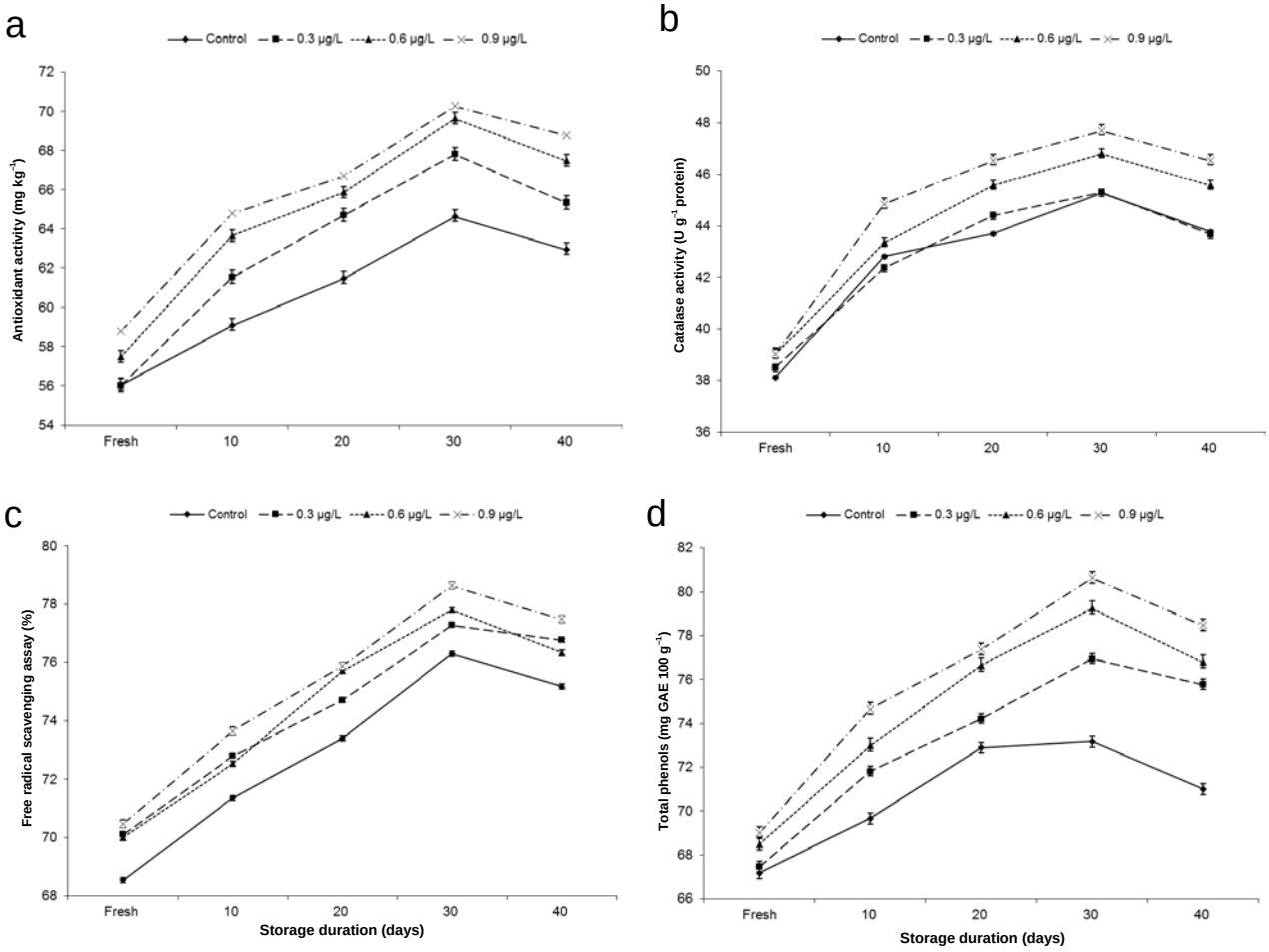

Fig. 3. Interactive effect of 1-MCP and storage duration on (a) antioxidant activity, (b) catalase activity, (c) free radical scavenging assay, (d) total phenols of peach

trations, peach fruits treated with 0.9 µg l^{-1} 1-MCP solution recorded the highest antioxidant activity (65.86 mg kg^{-1}). The lowest antioxidant activity (57.23 mg kg^{-1}) was recorded in peach fruits for the control treatment (Fig. 1a). For the means of storage duration, more antioxidant activity (66.33 mg kg^{-1}) was observed in peach fruits stored for 30 days, which was statistically different from the rest of treatment followed by antioxidant activity (65.81 mg kg^{-1}) in peach fruits stored for 30 days. The lowest antioxidant activity (57.07 mg kg^{-1}) was observed in freshly harvested fruits (Fig. 2a). The interactive effect of 1-MCP concentration and storage duration revealed that more antioxidant activity (70.27 mg kg^{-1}) was recorded in peach fruits treated with 0.9 µg l^{-1} 1-MCP solution, stored for 30 days. The lowest antioxidant activity (56.03 mg kg^{-1}) was recorded in freshly harvested peach fruits of control treatment (Fig. 3a).

Catalase activity (U g^{-1} FW). 1-MCP levels, storage duration, and their interaction had significant effect on catalase activity of peach fruits (Tab. 1). The data for 1-MCP levels showed that more catalase activity (46.93 U g^{-1} FW) was recorded in peach fruits dipped in 0.9 µg l^{-1}. The lowest catalase activity (41.93 U g^{-1} FW) was observed in peach fruits of the control treatment (Fig. 1a). Regarding the means for storage duration, the highest catalase activity

(47.75 U g^{-1} FW) was recorded in peach fruits stored for 30 days followed by catalase activity (46.42 U g^{-1} FW) in peach fruits kept for 20 days in storage, while freshly harvested peach fruits showed the lowest catalase activity (34.27 U g^{-1} FW) (Fig. 2a). Regarding the means for the interactive effect of 1-MCP concentration and storage duration, more catalase activity (51.63 U g^{-1} FW) was recorded in peach fruits dipped in 0.9 µg l^{-1} stored for 30 days, while the lowest catalase activity (34.11 U g^{-1} FW) was recorded in freshly harvested peach fruits of control treatment (Fig. 3b).

Free radical scavenging assay (%). The data for free radical scavenging assay revealed that 1-MCP levels, storage durations, and their interaction significantly affected the free radical scavenging assay of peach fruits (Tab. 1). Data recorded for free radical scavenging assay revealed that more activity of free radical scavenging (75.22%) was recorded in peach fruits dipped in 0.6 µg l^{-1} 1-MCP solution followed by free radical scavenging assay (74.48 and 74.33%) observed in peach fruits dipped in 0.3 and 0.9 µg l^{-1} 1-MCP solution. However, the lowest activity of free radical scavenging assay (72.96%) of peach fruits was recorded in control treatment (Fig. 1b). The highest free radical scavenging assay (77.50%) was recorded in peach fruits stored for 30 days. The lowest free radical scavenging assay (69.79%) was observed in freshly harvested peach fruits (Fig. 2b). The interaction between 1-MCP and storage duration showed that the highest activity of free radical scavenging assay (78.63%) was recorded in peach fruits dipped in 0.6 µg l^{-1} 1-MCP solution, stored for 30 days. The lowest free radical scavenging assay (68.55%) was recorded in freshly harvested peach fruits of control treatment (Fig. 3c).

Total phenols (mg GAE 100 g^{-1}). The analysis of data showed that total phenols of peach fruit were significantly affected by 1-MCP concentrations, storage durations and their interaction (Tab. 1). Regarding the means for 1-MCP levels, increasing 1-MCP levels from control to 0.9 µg l^{-1} significantly increased the total phenolic content of peach fruits from 68.08 to 76.02 mg GAE 100 g^{-1} (Fig. 1b). Total phenolic content of peach fruits was also significantly affected by storage duration. The highest total phenolic content (76.60 mg GAE 100 g^{-1}) was observed in peach fruits stored for 30 days, followed by total phenolic content (75.09, 74.10 and 71.66 mg GAE 100 g^{-1}) in peach fruits stored for 40, 20 and 10 days, respectively. However, freshly harvested fruits showed the lowest total phenolic content (67.75 mg GAE 100 g^{-1}) of peach fruits (Fig. 2b). The interactive effect of 1-MCP and storage duration on total phenolic contents of peach was also found significant. The highest total phenolic (80.63 mg GAE 100 g^{-1}) content was observed in peach fruits stored for 30 days, dipped in 0.9 µg l^{-1} 1-MCP solution. The lowest total phenolic content (68.01 mg GAE 100 g^{-1}) was observed in freshly harvested peach fruits dipped in 0.3 µg l^{-1} 1-MCP solution (Fig. 3d).

Ascorbic acid content (mg 100 g^{-1}). The analysis of data showed that ascorbic acid content was significantly affected by the post-harvest application of 1-MCP concentrations, storage durations and their interaction (Tab. 1). Regarding the means for 1-MCP levels, the highest ascorbic acid (6.19 mg 100 g^{-1}) was recorded in each fruit dipped in 0.6 µg l^{-1} 1-MCP solution, followed by ascorbic acid (6.12 and 6.11 mg 100 g^{-1}) in peach fruits treated with 0.3 and 0.9 µg l^{-1} 1-MCP solution, respectively. However, the lowest ascorbic acid (6.03 mg 100 g^{-1}) content was recorded in peach fruits of control treatment (Fig. 4a). The highest ascorbic acid (6.25 mg 100 g^{-1}) content was observed in freshly harvested peach fruits, followed by ascorbic acid contents (6.22, 6.15 and 6.05 mg 100 g^{-1}) noted in fruits stored for 10, 20 and 30 days, respectively. While peach fruits kept for 40 days in storage showed the lowest ascorbic acid (5.88 mg 100 g^{-1}) content (Fig. 4b). The interactive effect of 1-MCP and storage duration was also found significant. More ascorbic acid (6.31 mg 100 g^{-1}) content of peach fruits was observed in fruits harvested as fresh, dipped in 0.6 µg l^{-1} 1-MCP solution. The lowest ascorbic acid content (5.73 mg 100 g^{-1}) was observed peach fruits of control treatment stored after 40 days (Tab. 2).

Weight loss (%). The analysis of data showed that weight loss was significantly affected by 1-MCP concentrations, storage durations and their interaction (Tab. 1). Regarding the means for 1-MCP levels, the highest weight loss (6.01%) was recorded in peach

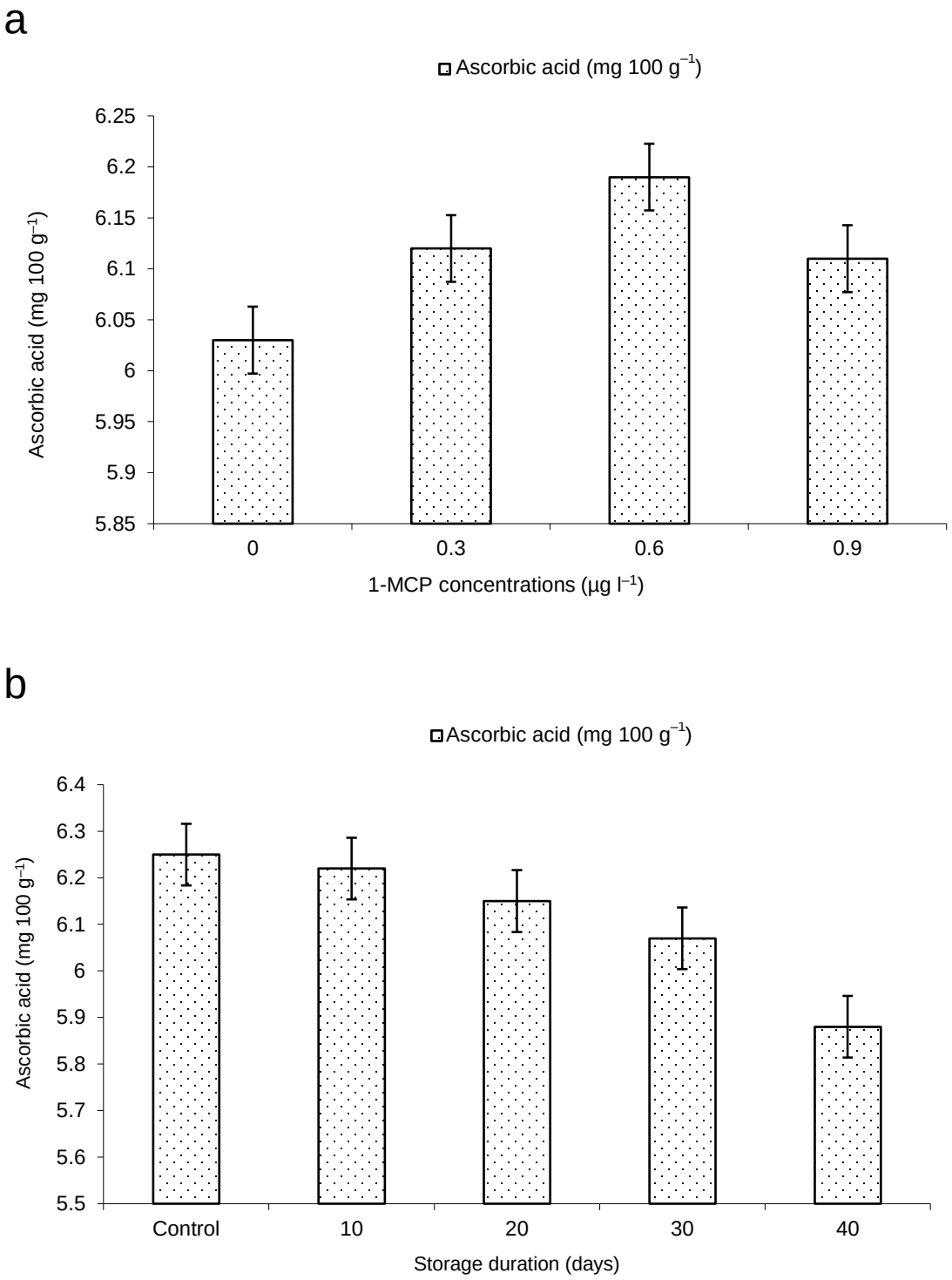

Fig. 4. Ascorbic acid of peach as affected by (a) 1-MCP concentration, (b) storage duration

Table 2. Interactive effect of 1-MCP concentrations and storage durations on weight loss (%), fruit decay (%) and ascorbic acid of peach

1-MCP concentration (µg l^{-1})	Storage duration (days)	Weight loss (%)	Fruit decay (%)	Ascorbic acid (mg 100 g^{-1})
0	fresh	0.00 l	0.00 k	6.21 cd
	10	4.57 i	6.57 h	6.18 def
	20	6.63 f	9.13 e	6.07 h
	30	8.60 c	9.60 c	5.96 ij
	40	10.23 a	11.73 a	5.73 l
0.3	fresh	0.00 l	0.00 k	6.26 abc
	10	4.33 j	6.33 i	6.23 bcd
	20	6.37 g	8.87 f	6.13 fg
	30	8.33 d	9.33 d	6.06 i
	40	10.33 a	11.83 a	5.93 j
0.6	fresh	0.00 l	0.00 k	6.31 a
	10	4.00 k	6.00 j	6.27 ab
	20	5.90 h	8.40 g	6.23 bcd
	30	7.90 e	8.90 f	6.13 efg
	40	9.93 b	11.43 b	6.00 i
0.9	fresh	0.00 l	0.00 k	6.23 bcd
	10	4.17 jk	6.17 ij	6.19 de
	20	6.00 h	8.50 g	6.16 efg
	30	8.20 d	9.20 de	6.11 gh
	40	10.27 a	11.77 a	5.87 k
$LSD_{p0.05}$ interaction		0.189	0.182	0.056

Means followed by the similar letter(s) in the column do not differ significantly from one another

fruits for the control treatment. The lowest weight loss (5.55%) was observed in peach fruits dipped in 0.6 µg l^{-1} 1-MCP solution (Fig. 5a). Weight loss of peach fruits was also significantly affected by the storage duration. The highest weight loss (10.19%) was observed in peach fruits stored for 40 days. The lowest weight loss (4.27%) was recorded in peach fruits stored for 10 days (Fig. 5b). The interactive effect of 1-MCP concentration and storage duration was also found significant. The highest weight loss (10.33%) was observed in peach fruits stored for 40 days dipped in 0.3 µg l^{-1} 1-MCP solution. The lowest weight loss (4.00%) was observed in peach fruits treated with 0.6 µg l^{-1} 1-MCP solution, stored for 10 days (Tab. 2).

Fruit decay (%). The post-harvest application of the 1-MCP solution, storage duration and their interaction had significant effect on fruit decay of peach fruits (Tab. 1). The highest percentage of fruit decay (7.41%) was recorded in peach fruits for the control treatment. The lowest percent fruit decay (6.95%) was recorded in peach fruits dipped in 0.6 µg l^{-1} 1-MCP solution (Fig. 5a). As concerned the means for storage durations, the highest percent fruit decay (11.69%) was recorded in peach fruits stored for 40 days. Peach fruits stored for 10 days recorded the lowest fruit decay (6.27%) (Fig. 5b). The interactive effect of 1-MCP concentration and storage duration had also a significant effect on fruit decay of peach fruits. More fruit decay (11.83%) was observed in peach fruits dipped in 0.3 µg l^{-1}, stored for 40 days. The lowest fruit decay (6.00%) was observed in peach fruits dipped in 0.6 µg l^{-1} 1-MCP solution, stored for 10 days (Tab. 2).

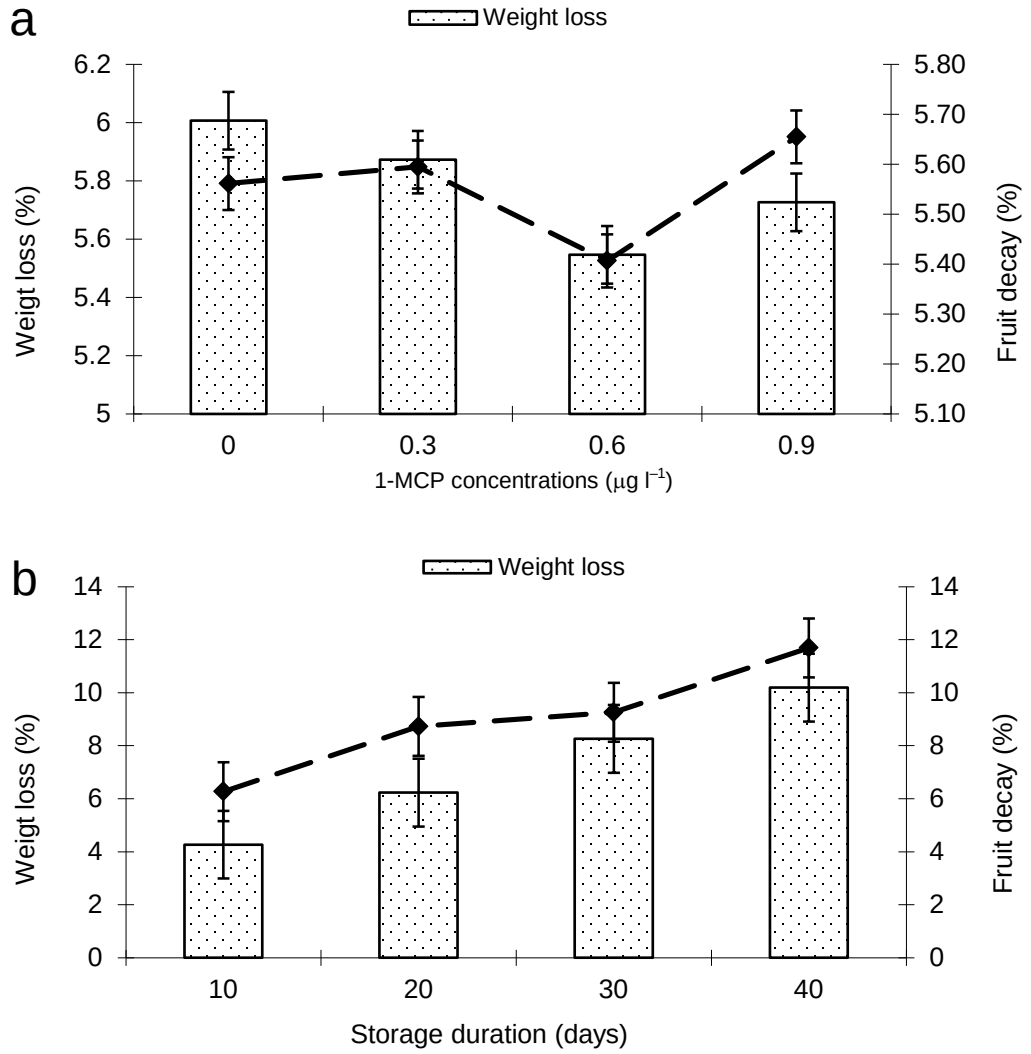

Fig. 5. (a) Effect of 1-MCP concentrations on weight loss (%) and fruit decay (%) of peach, (b) effect of storage duration on weight loss (%) and fruit decay (%) of peach

DISCUSSION

In the present study, the increase in 1-MCP concentration from control to 0.9 µg l^{-1} gradually increased the free radical scavenging activity (FRSA) from 2 to 3% in peach fruits (Fig. 1). Fruit antioxidants are thought to protect the tissues against any stress or diseases. Resistance against post-harvest diseases is induced by specific antifungal molecules such as phenolic compounds. These compounds may act to enhance the quality as well as extend the post-harvest life of the peach fruits [Di-Vaio et al. 2008]. The antioxidant activity influenced the vitamins andseveral polyphenolic compounds in fruits result in high FRSA [Akhtar 2010]. The post-harvest storage life is determined by antioxidant activity, which is concerned with some physical and chemical attributes like peel color and flesh firmness [Dalla et al. 2007]. Furthermore, 1-MCP concentrations might have counteracted for balanc-

ing the increased free radicals with increased FRSA [Di-Vaio et al. 2008].

Among the antioxidative enzymes, catalase is one of the most important enzymes that are involved in the control of reactive oxygen species (ROS), particularly H_2O_2 (hydrogen peroxide) [Foyer 1993]. In the present study, highest catalase activity (12%), total phenols (12%) and antioxidant activity (15%) in peach fruits were recorded with 0.9 µg l^{-1} 1-MCP application as compared to the control and the rest of 1-MCP treatments (Fig. 1b). Increased catalase activity, phenolic compounds, and antioxidant activity are key defensive actions against oxidative damages, while lower catalase activity weakens the capability of cells to scavenge H_2O_2 [Foyer 1993]. Fruit senescence positively correlates with antioxidant enzymes [Lemoine 2010]. To overcome the oxidative damage of fruits during storage, plants had developed a well-integrated antioxidant system, which includes enzymatic and non-enzymatic components that delayed the senescence process [Lemoine 2010]. In the present study, it was observed that 1-MCP greatly increased the antioxidant activity of peach fruits (Fig. 1b), which is confirmed by Tavallali and Moghadam [2015]. This system is further strengthened by post-harvest application of 1-MCP [Tavallali and Moghadam 2015]. Loss of antioxidant activity during storage period is due to the large amount of antioxidant compounds consumption in defense of free radicals and cold storage stress [Gulen and Eris 2004]. In the present research, total antioxidant activity (7%) and phenols (13%) declined during the last 10 days of storage. This might be due to the fact that the breakdown of toxic metabolites caused all the activity to slow down and other injuries caused by oxygen stress [Kaynara et al. 2005], hence leading to the softening of fruits and ultimately resulted in the reduced post-harvest quality of peach fruits. All these processes were effectively controlled by the application of 1-MCP. Flavor and color are determined by phenolic content present in the fruit. Phenolics are secondary metabolites that are synthesized by all plants. Phenolics are involved in several plant functions like photosynthesis, nutrient absorption in plants, synthesis of protein and enzymatic activities [Jeong et al. 2008]. 1-MCP, being a recent technology, has the ability to be used as a commercial technology due to its ability to uphold the capability of antioxidant capacity, hence delaying the ripening process [Ilic et al. 2013], which greatly confirms the present results.

The reason for the improvement in ascorbic acid might be due to the fact that application of 1-MCP reduces the gene expression of ascorbate peroxidase (a major oxidative enzyme of ascorbic acid) [Ma et al. 2010] hence retained the ascorbic acid in peach. Previous studies revealed that ethylene inhibitors limit the fruit respiration metabolism and fungal growth, thereby delaying the decline of nutritional components such as soluble solids, ascorbic acid and titratable acidity [Hagenmaier 2005]. Treatment with 1-MCP slowed vitamin C loss in peaches [Liu et al. 2005], which greatly confirmed the present results. The effectiveness of 1-MCP has been proven in many types of research carried out on peaches [Hayama et al. 2008], which greatly confirmed the present results. These authors reported that qualitative attributes of the above-mentioned crops were significantly improved by the application of 1-MCP. Ascorbic acid content of mango was retained by treating the fruits with 1-MCP as compared to the control [Sivakumar et al. 2012].

Resistance to fruit decay and reduction in weight loss is generally related to the degree of ripeness. In the present study, disease incidence and weight loss were minimized by 8 and 6%, respectively, due to the delay in ripening process as a result of 1-MCP treatment (Tab. 2, Fig. 5a). The reason for the increase in disease resistance might be attributed to the enhanced activity of certain enzymes like PAL (phenylalanine ammonia-lyase), PPO (*polyphenol oxidase)* and POD (peroxidase) [Chappell et al. 1984]. Increased PAL activity is closely linked with the synthesis of toxic metabolites such as phytoalexins, phenols, and lignins in the defense pathway of the plant. Treatment of I-MCP enhances the synthesis of these toxic compounds, which results in suppression of disease incidence of peach fruits [Chappell et al. 1984]. The increase in weight loss and disease incidence during storage might be due to softening of peach fruits during storage. Softening of fruits involves series of changes in the polysaccharide of

middle lamella and primary cell wall [Fischer and Bennett 1991]. Other reason of softening during storage could be the hydrolysis of polysaccharides and modification in the polymers bonds established with turgor alterations, which resulted in increased cell separation and softening of the cell wall [Brummell 2006]. Furthermore, the increased activities of the cell wall degrading enzymes such as pectin esterase (PE), *endo*-1,4-*β*-glucanase (EGase), *exo*-polygalacturonase (*exo*-PG) and *endo*-polygalacturonase resulted in softening of peach fruits, hence increasing the ripening process of peach [Ullah et al. 2013], which increased the rate of respiration resulted in the weight loss of fruit. These changes let the door open for an attack of pathogens and microorganisms. Application of 1-MCP significantly retained the weight loss and minimized the attack of disease (Tab. 2, Fig. 1), which is a clear indication that 1-MCP had a major role in controlling the biochemical changes occurring in the fruit [Liu et al. 2005]. In peach, fruit softening has been found to be associated with a depolymerization of matrix glycans both loosely and tightly attached to the cellulose and a loss of galacturonic acids from all cell wall fractions [Ortiz et al. 2011], which were effectively controlled by the application of 1-MCP [Hayama et al. 2008]. Reduction in the rate of respiration due to the application of 1-MCP could be the reason that contributed to the reduction of weight loss [Liu et al. 2005]. Treatment with 1-MCP showed a low weight loss probably due to a protective role on fruit peel integrity, which reduced water evaporation, gas exchange and decreased the nutrient loss [Tavallali and Moghadam 2015].

CONCLUSIONS

1. Peach fruits treated with 0.6 µg l^{-1} 1-MCP solution significantly retained the ascorbic acid content of peach fruits for 40 days.

2. However, higher free radical scavenging assay, catalase activity, antioxidant activity, total phenols and lower weight loss and fruit decay were observed in peach fruits treated with 0.9 µg l^{-1} 1-MCP for 30 days.

3. A gradual increase in free radical scavenging assay, catalase activity, total phenols and antioxidant activity was observed due to the application of 1-MCP at 0.9 µg l^{-1} for 30 days and observed a declined onwards.

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