SEQUENTIAL TREATMENTS OF HOT WATER AND MODIFIED ATMOSPHERE PACKAGING IN CHERRY TOMATOES

BULENT AKBUDAK, NURAY AKBUDAK, VEDAT SENIZ and ATILLA ERIS[1]

Department of Horticulture
Faculty of Agriculture
University of Uludag
Gorukle, 16059 Bursa, Turkey

ABSTRACT

*The effects of hot water treatment (HWT) and modified atmosphere packaging (MAP) on the storage and fruit quality of cherry tomatoes (*Lycopersicon esculentum *Mill. cvs. "Alona" and "Naomi") were investigated. For this purpose, light-red cherry tomato fruits were dipped in hot water (54C for 5 min) and subsequently stored in plastic film materials with various* O_2 *and* CO_2 *permeabilities. The cultivars used in the study were stored in a cold room at 5–7C and 90 ± 5% relative humidity (RH). The changing gas composition within the films and quality changes of the fruits were evaluated during the storage period. At the end of the study, HWT combined with MAP produced better results than MAP alone in both cultivars. Therefore, the HWT + MAP treatment proved effective with regard to fruit quality and delaying the maturity of cherry tomatoes during storage. HWT +* 50 *micropolyethylene (μPE) treatment produced the best result in the two cultivars at the end of the 28-day storage with respect to the parameters evaluated in the study.*

PRACTICAL APPLICATIONS

Tomato is considered a climacteric fruit, in which ripening is accompanied by a peak in respiration and a concomitant sharp increase in ethylene production, which accelerates quality loss through the physicochemical changes related to this process, such as softening and color evolution. Postharvest heating is a noncontaminating physical treatment that delays the ripening process, reduces chilling injury and controls the activity of pathogens. Because of these beneficial effects, heat treatments are currently used com-

[1] Corresponding author. TEL: +90-224-2941472; FAX: +90-224-4429098; EMAIL: atillaer@uludag.edu.tr

Journal of Food Quality **30** (2007) 896–910.

mercially for quality control of fresh products. Modified atmosphere packaging is another technique that has been used to prevent or retard postharvest fruit ripening and its associated biochemical and physiological changes by favorably altering the O_2 and CO_2 levels around the products. In recent years, the use of combined techniques in the postharvest handling of fresh products is increasing, and numerous authors have obtained good results using a combined treatment. Diseases have the potential to destroy the market value and utility of large amounts of fresh tomato annually. The present work evaluated a prestorage conditioning treatment to protect against these losses. The results will allow the long storage of cherry tomato, benefiting the growers, exporters, shippers and distributors of this horticultural product.

INTRODUCTION

Postharvest heating is a noncontaminating physical treatment that delays the ripening process, reduces chilling injury and controls the activity of pathogens. As a result, heat treatments are currently used commercially in the quality control of fresh products. Modified atmosphere packaging (MAP) is another technique that has been used to prevent or retard postharvest fruit ripening and the associated biochemical and physiological changes by favorably altering the O_2 and CO_2 levels around the products (Lurie 1998; Day 2002; Trindade *et al.* 2002). In recent years, the use of combined techniques in postharvest handling of fresh products is increasing, and numerous authors have obtained good results using a combined treatment (Lurie and Sabehat 1997; McDonald *et al.* 1999; Ferguson *et al.* 2000; Itoh 2003; Tuan *et al.* 2004).

Immediately after harvest, cherry tomatoes present a sudden increase in metabolic activity. Prompt cooling and hot water treatment (HWT) after harvest is therefore of major importance. In addition to temperature, metabolic activity is strongly influenced by atmosphere composition. These storage conditions slow the physiological processes associated with ripening. Quality requirements of minimally processed products generally specify that the produce should be visually acceptable and appealing, have a fresh appearance, be of consistent quality and be reasonably free from defect. Therefore, other postharvest treatments, such as coatings, HWT and controlled/modified atmosphere storage, may also significantly extend product quality.

Our objective was to examine the combined effect of heat treatment and MAP obtained by film materials of selected permeability on the quality retention of fresh products during storage. In this way, the effect of these methods on specific products such as cherry tomatoes were investigated and it was aimed to determine the optimum cultivar and film material for prolonging the commercial life of these products in the study.

MATERIALS AND METHODS

Fruit Material

Cherry tomatoes (*Lycopersicon esculentum* Mill. cvs. "Alona" and "Naomi"), in the light-red stage (more than 60% of the surface shows pinkish-red or red, but less than 90% of the surface shows red color, United States Department of Agriculture (USDA) Color Stage 5) (Trejo and Cantwell 1996), were harvested from the Uludag University, Faculty of Agriculture, Department of Horticulture Research and Training greenhouse. Undamaged fruits of the same size were selected for the experiment.

Treatments

Fruits were divided into two lots: heat treatment and control. One lot was dipped in hot water (54C) for 5 min. A Nüve BM 101 (Laboral Co., Bursa, Turkey) water bath with a temperature range of 0–100C was utilized for heat treatment. The other lot was dipped in tap water. After air-drying, 500 g of tomato in plastic boxes from the treated and nontreated lots were enclosed in plastic film packages and sealed by a Petra FS 500 (Metro Co., Bursa, Turkey) plastic-covering machine. For this purpose, MAP studies were carried out by using 50 micropolyethylene (µPE) with an O_2 permeability of 303.20 mL/mdayatm^2 and a CO_2 permeability of 64.27 mL/mdayatm^2, and by using 100 µPE with an O_2 permeability of 116.60 mL/mdayatm^2 and a CO_2 permeability of 112.40 mL/m/day/atm^2 at 5C. All treatments in normal (NA) and MAP of the treated and nontreated fruit were stored in 5–7C and 90 ± 5% relative humidity (RH).

Quality Parameters

Parameters such as weight loss (%), total soluble solids (TSS) (%), firmness (N), titratable acidity (TA) (%), ascorbic acid (mg/100/g), lycopene (µg/g), beta-carotene (µg/g), and the ratio of O_2 and CO_2 in MAP (%) were observed in the cherry tomatoes throughout the storage period at 7-day intervals.

Weight losses occurring in fruits at each analytical period during storage were determined using a Densi AC 100 precision balance (5-g precision) (Densi Industrial Balance Systems Co., Istanbul, Turkey), considering the former weight value in each analytical period. TSS of tomato juice was determined using a NOW refractometer (0–32%) (Tech-Jam International Inc., Tokyo, Japan) at 20C, and the results were reported as a percentage. Firmness measurements of fruits were made using a 5/16-in. probe with an FT 327 penetrometer (Winopal Forschungsbedarf GmbH, Ahnsbeck, Germany) in each one of the fruits, and the firmness values were read as N. To ascertain the TA, tomato puree was titrated with 0.1 N NaOH to pH 8.1, and the results were expressed as the percentage of citric acid. Ascorbic acid was determined by subjecting the samples taken from the fruits, forming the replicate to extraction with oxalic acid (0.4%), and then reading and calculating the absorbancy values at 520 nm in a spectrophotometer (Shimadzu UV-120-01, Shimadzu Co., Duisburg, Germany) (Holden 1976). The lycopene and beta-carotene contents of the tomato samples were determined by centrifuging the prepared solutions at 3,000 rpm for 5 min, then treating with petroleum ether, centrifuging again, subjecting to extraction with acetone, and finally reading and calculating from the spectrophotometer at 452 and 505 nm (Kilic *et al.* 1991). A Dräger Multiwarn II gas analyzer (Drägerwerk AG, Lübeck, Germany) was used to determine the O_2 and CO_2 concentrations under the plastic film material forming the MAP.

Statistical Analysis

The research was conducted using a randomized plots factorial experimental design. The analyses were made in three replications, with 500 g of fruit in each replicate. The cherry tomato cultivars and each analyses period used in the study were evaluated independently. Analysis of variance was performed and the means were compared by the least significant difference tested at a significant level of 0.05.

RESULTS AND DISCUSSION

Weight Loss

In the trial carried out on the storage of cherry tomatoes, the weight losses increased in line with ripening, which occurred during the prolonged storage period of the fruits. Moreover, significant differences were of the weight loss of the fruits during storage, depending on the treatments. Weight loss values, which were quite high in NA treatment, remained at low levels in the other treatments. The lower weight losses in fruits, compared with NA, are attributed to low rates of water loss in fruits caused by the limitation of atmosphere. Apparently, the atmospheres surrounding the fruits were a good barrier to moisture transfer. The lowest weight loss in the two cultivars was observed in HWT + 50 μPE treatment when the changes in this parameter were examined on the basis of cultivars (Tables 1 and 2). The low weight loss trend in the low O_2 and high CO_2 may be related to water vapor accumulation within the plastic

TABLE 1.
WEIGHT LOSS, TSS, FIRMNESS AND TA CHANGES OF CHERRY TOMATO CV. "ALONA" DURING STORAGE

Storage period (days)	Treatment 1	Treatment 2	Weight loss (%)	TSS (%)	Firmness (N)	TA (%)
0	HWT	NA	0.00	3.30a	13.05a	0.65a
	NoHWT		0.00	3.30a	13.15a	0.68a
LSD			–	–	2.65	0.04
7	HWT	NA	0.00	3.70b	14.72a	0.67a
		50 μPE	0.00	3.80ab	17.95a	0.64ab
		100 μPE	0.00	3.83ab	7.85b	0.67a
	NoHWT	NA	0.00	4.00a	6.57b	0.56c
		50 μPE	0.00	3.90ab	15.11a	0.59bc
		100 μPE	0.00	4.00a	2.94c	0.57c
LSD			–	0.21	1.76	0.07
14	HWT	NA	2.62b	4.24c	8.24a	0.62a
		50 μPE	0.57c	3.90d	9.22a	0.63a
		100 μPE	0.65c	4.80a	3.34b	0.61ab
	NoHWT	NA	3.75a	4.60ab	5.30ab	0.50c
		50 μPE	0.89c	4.07bc	8.83a	0.62a
		100 μPE	0.74c	4.37bc	5.89ab	0.58b
LSD			0.45	0.31	2.36	0.05
21	HWT	NA	4.32b	5.33b	3.63b	0.45bc
		50 μPE	0.71c	4.30c	6.57ab	0.65a
		100 μPE	0.87c	4.60c	4.91ab	0.57abc
	NoHWT	NA	7.23a	5.94a	2.94b	0.38c
		50 μPE	1.45c	4.60c	5.59ab	0.58ab
		100 μPE	1.54c	5.14b	9.52a	0.50abc
LSD			0.90	0.31	2.20	0.20
28	HWT	NA	8.19a	6.74a	6.87a	0.50a
		50 μPE	1.43b	4.34d	7.85a	0.55a
		100 μPE	1.64b	6.07b	2.94a	0.40b
	NoHWT	NA	12.40a	6.90a	1.67a	0.26c
		50 μPE	1.82b	4.50d	3.92a	0.50a
		100 μPE	2.10b	5.30c	2.65a	0.40b
LSD			5.51	0.47	6.67	0.06

Means in the same column followed by different letters are significantly different as determined by LSD test ($P < 0.05$).
HWT, hot water treatment; NoHWT, no hot water treatment; NA, normal atmosphere; μPE, micropolyethylene; LSD, least significant difference; TSS, total soluble solids; TA, titratable acidity.

containers during storage. The results show that softening would commence later in the fruits because of the weight loss of fruits subjected to low O_2 and high CO_2. So the positive effects of the storage of fresh preclimacteric fruits in sealed plastic films may be, in certain cases, a combination of its effects on the O_2 and CO_2 content within the fruit and the maintenance of high moisture content. The effect of moisture content is more likely a reduction in stress of

TABLE 2.
WEIGHT LOSS, TSS, FIRMNESS AND TA CHANGES OF CHERRY TOMATO CV. "NAOMI" DURING STORAGE

Storage period (days)	Treatment 1	Treatment 2	Weight loss (%)	TSS (%)	Firmness (N)	TA (%)
0	HWT	NA	0.00	3.00a	17.61a	0.63a
	NoHWT		0.00	3.00a	17.95a	0.65a
LSD			–	–	2.52	–
7	HWT	NA	0.00	3.60bc	19.62a	0.62a
		50 µPE	0.00	3.50c	22.86a	0.59a
		100 µPE	0.00	3.63a	13.44b	0.62a
	NoHWT	NA	0.00	3.77a	11.48b	0.50c
		50 µPE	0.00	3.70ab	20.31a	0.57ab
		100 µPE	0.00	3.76a	7.26c	0.52bc
LSD			–	0.10	1.93	0.06
14	HWT	NA	1.85a	5.16a	13.15a	0.55b
		50 µPE	0.36b	4.23c	14.42a	0.58a
		100 µPE	0.70b	5.20a	3.24b	0.56ab
	NoHWT	NA	2.79a	5.34a	6.57b	0.45d
		50 µPE	0.74b	4.34bc	13.15a	0.57ab
		100 µPE	0.93b	4.83ab	7.16b	0.51c
LSD			0.78	0.55	2.84	0.03
21	HWT	NA	2.98b	5.77ab	6.87ab	0.40c
		50 µPE	0.60e	4.67c	10.79a	0.61a
		100 µPE	1.00de	5.00bc	5.59b	0.58a
	NoHWT	NA	5.37a	6.34a	4.32b	0.29d
		50 µPE	1.24cd	5.00bc	8.53ab	0.54ab
		100 µPE	1.64c	5.87a	11.48a	0.50b
LSD			0.46	0.84	2.35	0.07
28	HWT	NA	4.20b	6.34b	9.81a	0.40b
		50 µPE	1.29c	4.60e	9.92ab	0.50a
		100 µPE	1.80c	5.43d	4.61bc	0.35b
	NoHWT	NA	7.43a	6.83a	2.65c	0.22c
		50 µPE	1.60c	5.80cd	4.32c	0.39b
		100 µPE	2.63bc	6.80bc	2.94c	0.33b
LSD			2.29	0.44	2.47	0.07

Means in the same column followed by different letters are significantly different as determined by LSD test ($P < 0.05$).
HWT, hot water treatment; NoHWT, no hot water treatment; NA, normal atmosphere; µPE, micropolyethylene; LSD, least significant difference; TSS, total soluble solids; TA, titratable acidity.

the fruit, which may be caused by a rapid rate of water loss in unwrapped fruit (Thompson 1998). Thompson (1998), Batu and Thompson (1998), Linke and Geyer (2002) and Aguayo *et al.* (2004) determined that the weight loss in tomato fruits wrapped with plastic film material had less altered atmospheric combinations compared with those stored unwrapped. Therefore, 50 µPE or polypropylene treatment produced better results with respect to weight loss in MAP. In a similar study, ripe tomato (cv. Pinky World) fruits were packaged in low-density PE and stored for 28 days at 4 or 10C. In this study, it was determined that fresh weight was better maintained at 4C and 40 μPE treatments (Kuenwoo *et al.* 2000).

TSS

Increases in the TSS value of fruits stored under different conditions were observed. These changes were found to be statistically significant (Tables 1 and 2). In the two cultivars, MAP treatment combined with HWT slowed down the changes in TSS values, indicating retardation in ripening. Moreover, the minimum increases in this parameter were recorded in cvs. "Alona" and "Naomi" from the HWT + 50 μPE treatment, with 4.34 and 4.50%, respectively. The TSS ratio, which is generally related to sugar-acid metabolism and mineral content, shows different changes depending on the storage temperature, atmosphere combination and maturity stage of the fruit. Especially high rates of CO_2 restricts this change under MAP conditions, which can be explained by the more limited change of carbohydrate content resulting from the suppression of respiration metabolism. Lurie and Klein (1992), Franschina *et al.* (1998) and McDonald *et al.* (1999) examined the changes in TSS during tomato storage and determined that the TSS contents of tomatoes increased during storage. Similar results were obtained in this study.

Firmness

The firmness values of stored fruits decreased with prolonged storage. The initial firmness values of cvs. "Alona" and "Naomi" were 13.15 and 17.95 N, respectively, whereas softening occurred toward the end of storage parallel to weight loss. However, softening proceeded more rapidly, especially in NoHWT + NA treatment of both cultivars (Tables 1 and 2). Generally, firmness values were higher, especially in the HWT + 50 μPE application in the fruits of both cultivars. The firmness values in the study of the two cultivars are an important result in view of the slower rate of softening and hence the physiological disorder occurring in these fruits. This situation may be explained by the direct suppression of the activities of pectin esterase and polygalacturonase enzymes leading to postharvest softening of the fruit structure or blockage of the synthesis of ethylene, which controls the activities of these enzymes, especially with MAP treatment. Thompson (1998) and Kuenwoo *et al.* (2000) determined that the lower the concentration of CO_2 in plastic film during the MAP storage of tomatoes, the better the fruit firmness would be, and that 50 μPE treatment gave good results with respect to firmness values among the PE film materials with different thickness.

TA

The TA values of cherry tomatoes decreased during storage (Tables 1 and 2). These reductions observed in TA values in relation to ripening resulted from the utilization of acids in respiration and other physiological processes, together with carbohydrates. Therefore, TA values were effective on the ripening of fruits, together with TSS values. Moreover, the atmosphere combinations were an important factor affecting the ripening of fruits, together with HWT. The highest TA value after storage was obtained from the HWT + 50 µPE treatment in both cultivars. In a similar study, Onwuzulu *et al.* (1996) determined that the ripening of fruits was retarded during the storage of tomatoes wrapped with a 120-gage low-density PE at 28C. In another study, mature green tomatoes were immersed in water at 38, 42, 46, 50 or 54C for 30, 60 or 90 min prior to storage at 2C for 2, 4 or 6 weeks. In this study, the HWT was determined to reduce the TA content of fruits (Hakim *et al.* 1998).

Ascorbic Acid

The ascorbic acid content of cherry tomatoes showed variations on a cultivar basis (Markovic *et al.* 2002). In this study, reductions were observed in the ascorbic acid value of cherry tomato cultivars during storage, although not statistically significant. Insignificant reductions were also determined by Lisiewska and Kmiecik (2000), Moretti *et al.* (2002), Raffo *et al.* (2002)and Giovanelli *et al.* (2001). However, the reductions in this study proceeded faster in the cv. "Alona." The highest results were obtained from the HWT + 50 µPE treatment, with 12.07 and 25.80 mg/100 g in cvs. "Alona" and "Naomi," respectively (Fig. 1). High-CO_2 treatment retarded the change as described earlier, but not in large amounts. In a number of studies, ascorbic acid loss was determined in the tomatoes stored at high temperatures under normal conditions (Kuenwoo *et al.* 2000, Giovanelli *et al.* 2001, Moretti *et al.* 2002; Lavelli and Giovanelli 2003).

Lycopene

Reductions occurred in the lycopene content of cherry tomato cultivars during NA and MAP storage (Fig. 2). Partial reductions in the lycopene contents of fruits proceeded somewhat faster, especially in the fruits that were not subjected to HWT. The lycopene value closest to the initial value in the study was obtained from the HWT + 50 µPE treatment. In other studies related to NA and MAP storage of tomatoes, it was determined that high-temperature treatments either stabilized or very slightly reduced the lycopene content, similar to the results obtained from this study (Lurie and Klein 1992; Hamauzu *et al.* 1998; Giovanelli *et al.* 2001; Lin and Chen 2004).

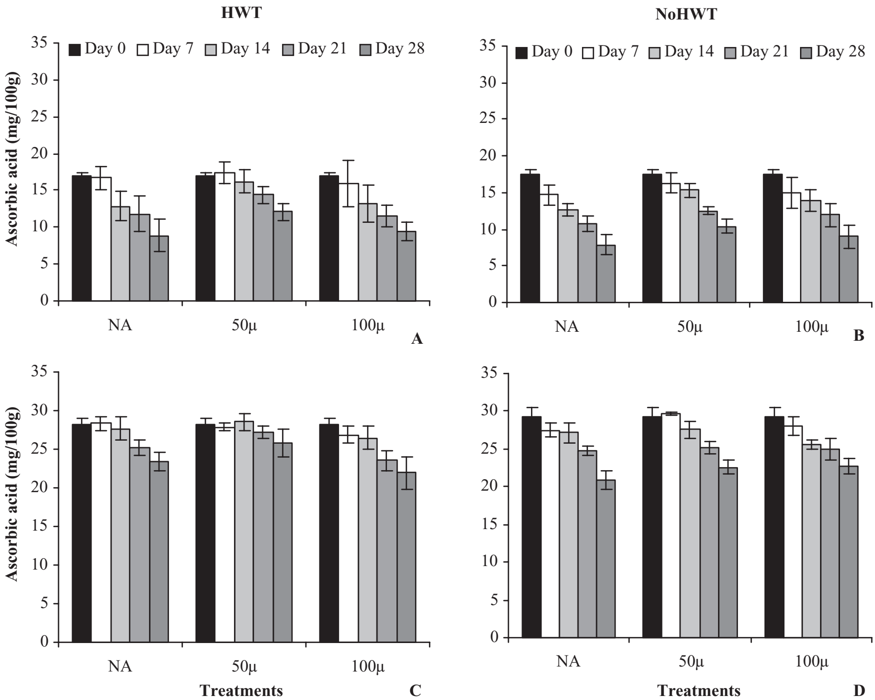

FIG. 1. CHANGES IN ASCORBIC ACID VALUES OF CHERRY TOMATO CVS. "ALONA" (A, B) AND "NAOMI" (C, D) DURING MAP (HWT: 50–100 µ: MAP-PE)
Vertical bars indicate standard error of the mean.
MAP, modified atmosphere packaging; HWT, hot water treatment; NoHWT, no hot water treatment; PE, polyethylene.

Beta-carotene

Beta-carotene content decreased with prolonged storage. The lowest beta-carotene content was determined in NoHWT at the end of storage in both cultivars. The highest beta-carotene content was obtained from the HWT + 50 µPE treatment in two cultivars (Fig. 3). The differences between HWT and NoHWT were found to be statistically significant. Temperature and MAP treatments had a significant effect in retarding the metabolically changes in fruits. Lisiewska and Kmiecik (2000) and Giovanelli *et al.* (2001) determined that statistically significant reductions would occur in the beta-carotene content of fruits depending on the storage period, similar to the results obtained from this study.

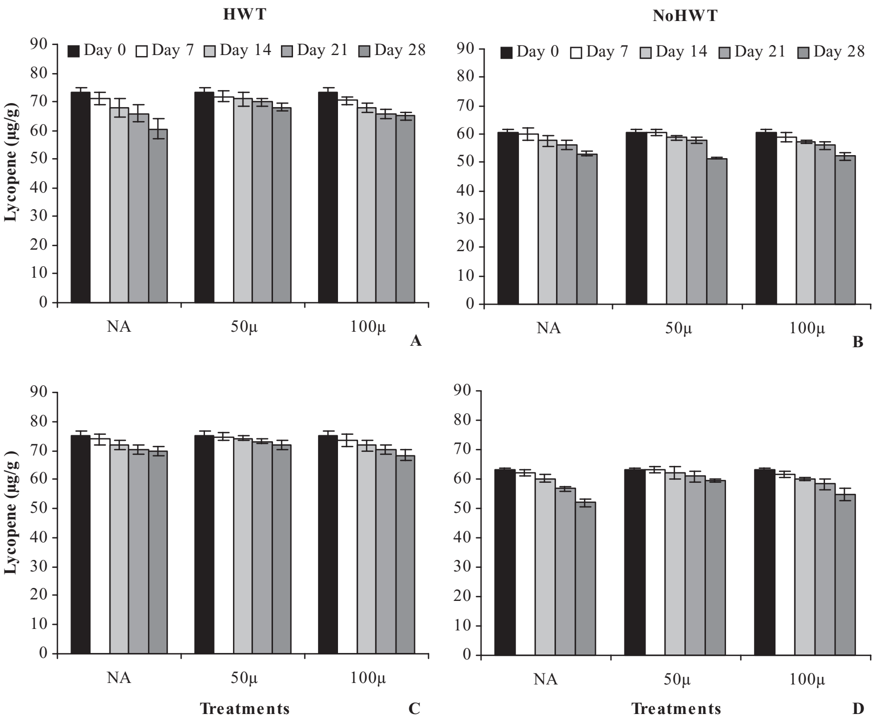

FIG. 2. CHANGES IN LYCOPENE VALUES OF CHERRY TOMATO CVS. “ALONA” (A, B) AND “NAOMI” (C, D) DURING MAP (HWT: 50–100 µ: MAP-PE)
Vertical bars indicate standard error of the mean.
MAP, modified atmosphere packaging; HWT, hot water treatment; NoHWT, no hot water treatment; PE, polyethylene.

The Ratio of O_2 and CO_2 in MAP

Reductions in O_2 and increases in CO_2 occurred following the transfer of tomato cultivars into MAP. Optimum O_2 and CO_2 ratios in cvs. “Alona” and “Naomi” at the end of storage were determined with the HWT + 50 µPE treatment (Figs. 4 and 5). Extreme reductions and increases in O_2 and CO_2 ratios originating from the permeabilities of plastic film materials lead to physiological disorders in fruits. Therefore, packaging films having moderate water vapor transmission rate and high gas permeability have been found more suitable for MAP of tomatoes. Concentration of O_2 in packs sealed with permeable films decreased and that of CO_2 increased during storage, after which a state of equilibrium was reached between respiration of the produce, and the diffusion of these gases was counterbalanced by production and consumption during respiration of the tomatoes and no further changes in the

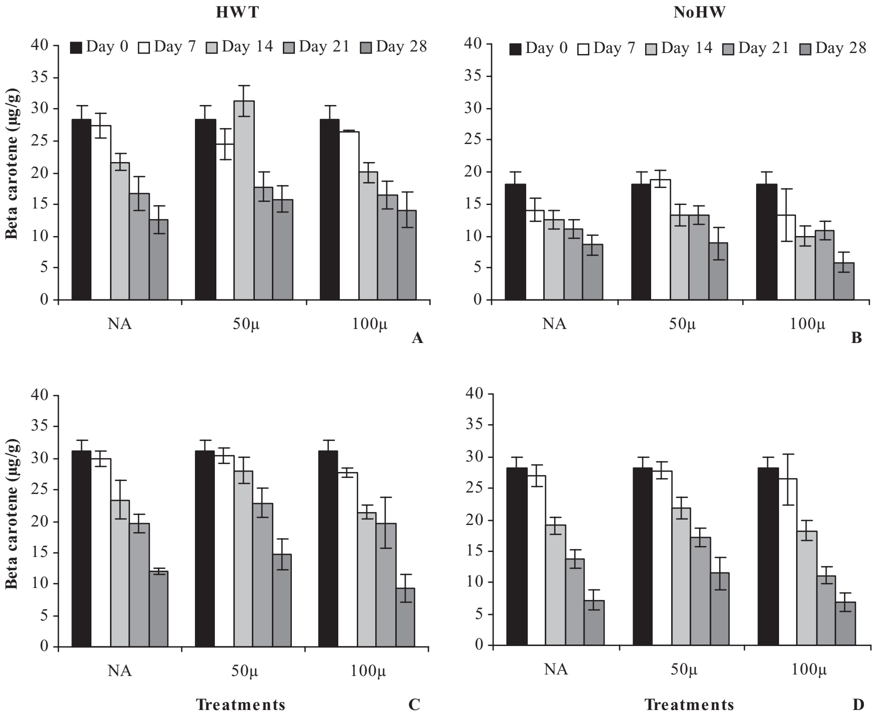

FIG. 3. CHANGES IN BETA-CAROTENE VALUES OF CHERRY TOMATO CVS. "ALONA" (A, B) AND "NAOMI" (C, D) DURING MAP (HWT: 50–100 µ: MAP-PE)
Vertical bars indicate standartd error of the mean.
MAP, modified atmosphere packaging; HWT, hot water treatment; NoHWT, no hot water treatment; PE, polyethylene.

gas concentration within the packs occurred with the fruit kept at constant temperature (Batu and Thompson 1998).

When the overall evaluation of fruits was considered, high rates of deterioration were observed in NA fruits, where high rates of weight loss were determined. Decay and spoilage was intensely observed in these fruits as a result of rapidly proceeding physiological events and fungal effects. Slower physiological processes in fruits subjected to HWT + MAP and lower incidence of spoilage in these fruits may be explained by the relation between the inactivation of fungi through HWT, and retention of fruit quality through MAP in terms of water loss. The tomatoes in MAP had a better overall appearance, as no shriveling resulting from weight loss was observed. The fact that these rates were especially high in NA fruits may stem from high O_2 and low CO_2. Moreover, in general, the severity of deterioration in fruits was markedly

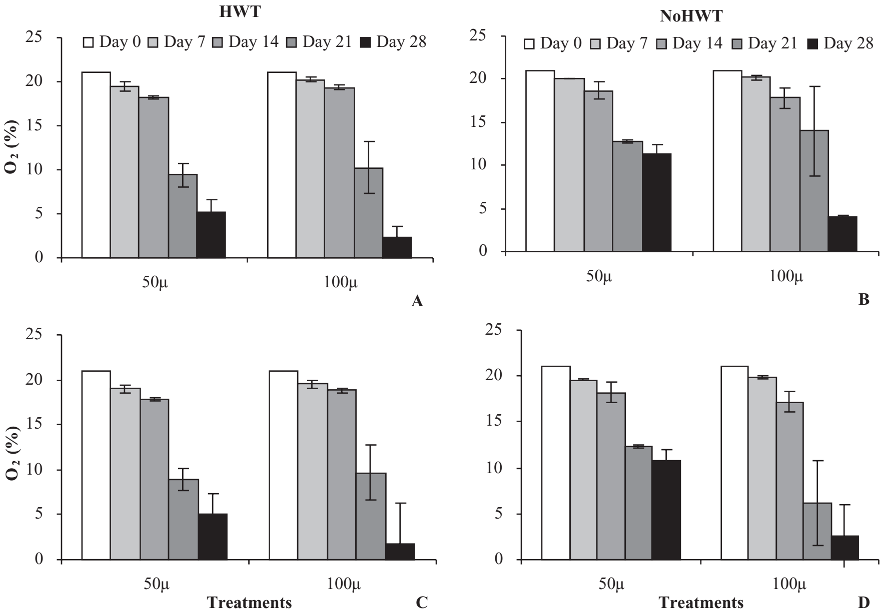

FIG. 4. CHANGES IN O_2 VALUES OF CHERRY TOMATO CVS. "ALONA" (A, B) AND "NAOMI" (C, D) DURING MAP (HWT: 50–100 µ: MAP-PE)

Vertical bars indicate standard error of the mean.

MAP, modified atmosphere packaging; HWT, hot water treatment; NoHWT, no hot water treatment; PE, polyethylene.

reduced through treatments of low O_2 and high CO_2. Thus, the rates of quality were better in low O_2 and high CO_2 in fruits treated with HWT, compared with NA fruits, which did not have any treatment. This was considered an important result with respect to the retention of quality of fruits during storage.

Consequently, these results suggest that the most important parameters to prolonging cherry tomato storage are variety, storage temperature, HWT and MAP. Moreover, the cherry tomatoes can be stored maximally for 1–2 weeks under NA conditions, whereas this period may be increased through different treatments under MAP conditions. Changes in the quality criteria of MAP fruits could be kept within determined ranges by combining MAP conditions with the HWT in our study. With this purpose, two film materials were used in order to see the effects of HWT and MAP treatments on the storage and fruit quality of cherry tomato cvs. "Alona" and "Naomi." Spoilage and maturity was accelerated in NA treatment. Moreover, changes in the quality parameters of fruits could be kept within the determined ranges by combining storage conditions with the HWT and different atmospheric treat-

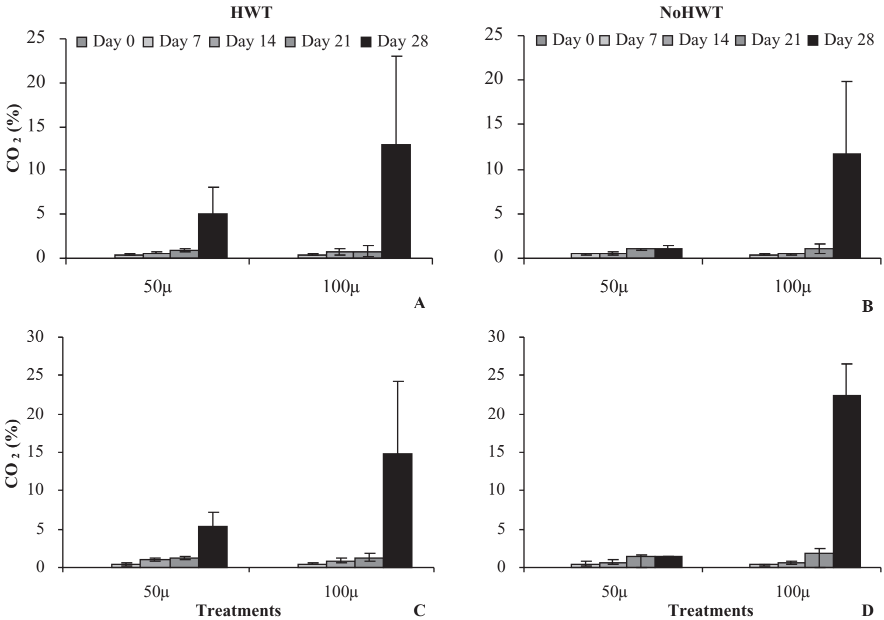

FIG. 5. CHANGES IN CO_2 VALUES OF CHERRY TOMATO CVS. "ALONA" (A, B) AND "NAOMI" (C, D) DURING MAP (HWT: 50–100 μ: MAP-PE)
Vertical bars indicate standard error of the mean.
MAP, modified atmosphere packaging; HWT, hot water treatment; NoHWT, no hot water treatment; PE, polyethylene.

ments. Disorders were reduced with HWT and low O_2 and high CO_2 during cold storage. Treatments prevented quality loss. In conclusion, the fruits of cherry tomato cvs. "Alona" and "Naomi" could successfully be stored for 28 days using HWT + 50 μPE, with slight changes in quality. Moreover, cv. "Naomi" gave partly better results compared with cv. "Alona," with respect to quality loss during storage.

ACKNOWLEDGMENT

The authors would like thank the May Seed Company Limited for supplying the seeds.

REFERENCES

AGUAYO, E., ESCALONA, V. and ARTES, F. 2004. Quality of fresh-cut tomato as affected by type of cut, packaging, temperature and storage time. Eur. Food Res Technol. *219*, 492–499.

BATU, A. and THOMPSON, A.K. 1998. Effects of modified atmosphere packaging on postharvest qualities of pink tomatoes. Turkish J. Agric. Forest *22*, 365–372.

DAY, B. 2002. Industry guidelines for high oxygen MAP of fresh prepared produce. Acta Hortic. *599*, 81–90.

FERGUSON, I.B., BEN-YEHOSHUA, S., MITCHAM, E.J., McDONALD, R.E. and LURIE, S. 2000. Postharvest heat treatments: Introduction and workshop summary. Postharvest Biol. Technol. *21*, 1–6.

FRANSCHINA, A., VARTORELLI, F., MOCCIA, S., MONACO, E. and CHIESA, A. 1998. Effect of maturity stage and temperature during tomato (*Lycopersicon esculentum* Mill.) storage. Acta Hortic. *464*, 486–496.

GIOVANELLI, G., LAVELLI, V., PERI, C., PAGLIORINI, E., ZANONI, B. and PETRONE, P. 2001. The antioxidant activity of tomato. IV. Effects of storage on oxidative and heat damage. Acta Hortic. *542*, 221–226.

HAKIM, A., KAUKOVIRTA, E., PEHU, E. and VOIPIO, I. 1998. Effect of hot water, immersion time, and length of storage on chilling injury of tomato fruit. Postharvest News Inform. *9*, 1938.

HAMAUZU, Y., CHACHIN, K. and UEDA, Y. 1998. Effect of postharvest storage temperature on the conversion of 14C-mevalonic acid to carotenes in tomato fruit. J. Jpn. Soc. Hort. Sci. *67*, 549–555.

HOLDEN, A. 1976. Chlorophylls. In *Chemistry and Biochemistry of Plant Pigments*, (T.W. Goodwin, ed.) pp. 1–37, Academic Press, London.

ITOH, K. 2003. Combined effects of hot water treatment (HWT) and modified atmosphere packaging (MAP) on quality of tomatoes. Packag. Technol. Sci. *16*, 171–178.

KILIC, O., COPUR, O.U. and GORTAY, S. 1991. Fruit and vegetable processing technology guide of practice. Uludag University, Faculty of Agriculture Lesson 7, p. 143.

KUENWOO, P., HOMIN, K., DONGMAN, K. and HYUNGWOO, P. 2000. Effect of the packaging films and storage temperatures on modified atmosphere storage of ripe tomato. Postharvest News Inform. *11*, 1082.

LAVELLI, V. and GIOVANELLI, G. 2003. Evaluation of heat and oxidative damage during storage of processed tomato products. II. Study of oxidative damage indices. J. Sci. Food Agric. *83*, 966–971.

LIN, C.H. and CHEN, B.H. 2004. Stability of carotenoids in tomato juice during storage. Food Chem. *90*, 837–846.

LINKE, M. and GEYER, M. 2002. Postharvest behaviour of tomatoes in different transport packaging units. Acta Hortic. *599*, 115–122.

LISIEWSKA, Z. and KMIECIK, W. 2000. Effect of storage period and temperature on the chemical composition and organoleptic quality of frozen tomato cubes. Food Chem. *70*, 167–173.

LURIE, S. 1998. Review postharvest heat treatments. Postharvest Biol. Technol. *14*, 257–269.

LURIE, S. and KLEIN, J.D. 1992. Ripening characteristics of tomatoes stored at 12C and 2C following a prestorage heat treatment. Sci. Hortic. *51*, 55–64.

LURIE, S. and SABEHAT, A. 1997. Prestorage temperature manipulations to reduce chilling injury in tomatoes. Postharvest Biol. Technol. *14*, 57–62.

MARKOVIC, Z., ZDRAVKOVIC, J., MIJATOVIC, M. and DAMJANOVIC, M. 2002. Breeding potential of local tomato populations for ß-carotene and vitamin C. Acta Hortic. *579*, 157–161.

McDONALD, R.E., McCOLLUM, T.G. and BALDWIN, E.A. 1999. Temperature of water heat treatments influences tomato fruit quality following low-temperature storage. Postharvest Biol. Technol. *16*, 147–155.

MORETTI, C.L., SARGENT, S.A., HUBER, D.J. and PUSCHMANN, R. 2002. Controlled atmosphere storage of tomato fruit with internal bruising. Hortic. Bras. *20*, 21–27.

ONWUZULU, O.C., PRABHA, T.N. and RANGANNA, S. 1996. Modified atmosphere storage of ripening tomatoes: Effect on quality and metabolism of ^{14}C-glucose and ^{14}C-acetate. Postharvest News Inform. *7*, 163.

RAFFO, A., LEONARDI, C., FOGLIANO, V., AMBROSINO, P., SALUCCI, M., GENNARO, L., BUGIANESI, R., GIUFFRIDA, F. and QUAGLIA, G. 2002. Nutritional value of cherry tomatoes (*Lycopersicon esculentum* cv. 'Naomi' F_1) harvested at different ripening stages. J. Agric. Food Chem. *50*, 6550–6556.

THOMPSON, A.K. 1998. *Controlled Atmosphere Storage of Fruits and Vegetables*, p. 278, CABI Publishing, Wallingford, UK.

TREJO, E. and CANTWELL, M. 1996. Cherry tomato storage and quality evaluations. Department of Vegetable Crops, University of California Davis, Tulare County, Vegetable Research Reports-Online. http://cetulare.ucdavis.edu/pubveg/che96.htm (accessed October 25, 2005).

TRINDADE, P., ABREU, M., COSTA, S.B., Costa, M.L.B., GONÇALVES, E.M. and MOLDAO-MARTINS, M. 2002. The effect of heat treatments and calcium chloride applications on quality of fresh-cut mango. Acta Hortic. *599*, 603–610.

TUAN, N.P., NAKANO, K. and MAEZAWA, S. 2004. Evaluation of the effect of hot water dipping on quality of fresh agricultural products. http://www.hcmuaf.edu.vn/hoithao/kck/evaluation (accessed August 5, 2005).