A short prestorage hot water rinse and brushing reduces decay development in tomato, while maintaining its quality

Ilic Zoran, Polevaya Yulia, Alkalai-Tuvia Sharon, Copel Azriel and Fallik Elazar
University of Prishtina, Faculty of Agriculture, 37000 Krusevac, Yugoslavia.
ARO-The Volcani Center, Department of Postharvest Science of Fresh Produce, Bet Dagan, 50250, Israel.
Corresponding author: Elazar Fallik, ARO-The Volcani Center, Department of Postharvest Science of Fresh Produce, P.O.Box 6, Bet Dagan, 50250, Israel. Fax ++972-3-9683622; e-mail: efallik@agri.gov.il

Accepted 22nd August 2001

ABSTRACT

The effectiveness of a short prestorage hot water rinsing and brushing (HWRB) was tested on decay incidence, quality parameters, respiration rate and ethylene evolution of pink tomato fruits that were kept for 14 days at 12°C plus 3 days at 20°C (storage and marketing simulation). Rinsing fresh harvested tomato at 52°C for 15 s while brushing significantly reduced decay development after storage and marketing simulation. This prestorage heat treatment maintained better fruit quality as evaluated by firmness, total soluble solids, acidity, and delayed fruit ripening as measured by significantly slower color development. In addition, the respiration rate and ethylene evolution of HWRB-52°C treated fruit was significantly lower than that of untreated fruit during storage and marketing simulation. Scanning electron microscopy showed that this method removed dirt and even fungal spores from the fruit skin.

Keywords: Heat treatment, *Lycopersicon esculentum*, storage and marketing simulation.

INTRODUCTION

Tomato is a widely distributed annual vegetable crop which is consumed fresh, cooked or after processing: by canning, making into juice, pulp, or as a variety of sauces. The tomato crop is adapted to a wide variety of climates ranging from the tropics to within a few degrees of the Arctic Circle. However, in spite of its broad adaptation, production is concentrated in a few warm and rather dry areas: more than 30% of world production comes from countries around the Mediterranean sea and another 20% from California (Cuartero and Fernandez-Munos 1999).

The optimum storage temperature of tomatoes is 12°C, but since pathological deterioration and continued ripening is not prevented at this temperature, tomatoes can be held only for short term storage (Hobson 1981). In addition, there is no registered postharvest fungicide for decay control of tomatoes caused mainly by fungi. This situation has prompted research into alternative, non-chemical methods of pathogen control.

Prestorage heat treatment of fruits and vegetables for decay control has been used for many years (Lurie 1998). Holding tomatoes at 38°C for 3 days prior to storage inhibited decay development without affecting fruit quality (Fallik *et al.* 1993). The use of hot water dips for several minutes was reported to control *in vitro* and *in vivo* spore germination and decay development of postharvest fungi in tomato (Barkai-Golan 1973). Recently, a new technology has been developed to rinse fresh agriculture produce with hot water for a short time (Fallik *et al.* 1996). This technology of a short hot water rising and brushing machine (HWRB) is used commecially in Israel, on several fresh commodities (Fallik *et al.* 1999;2000; Lichter *et al.* 2000; Porat *et al.* 2000; Prusky *et al.* 1999).

The objective of this study was to determine the effectiveness of prestorage HWRB on the quality and ripening characteristics of fresh pink tomato.

MATERIALS AND METHODS

Heat treatments and quality parameters

Tomato (*Lycopersicon esculentum* Mill. cv. 189) fruits of uniform size (about 150±5 g), pink colour and without any defects were picked directly from a commercial greenhouse in the central part of Israel. Fruit calyx was removed prior to the experiments. Fruits were randomly divided into groups of 10 per [illegible] treatment and were placed on rotating brushes and rinsed with hot water (HWRB) at 48, 52 and 56°C for 15 sec. and dried as described by Fallik *et al.* (1999).

Abbreviations: FID- Flame ionization detector; HWRB- [illegible] g electron microscopy; TA- Titratable acidity; TCD- Thermal conductivity detector; TSS- Total soluble solids; TWRB- Tap water rinsing and brushing; UF- Units of firmness;

Following these treatments fruits were stored at 12°C for 14 days and an additional 3 days at 20°C (simulation of sea transport and marketing from Israel to Europe). Untreated fruits or fruits that were rinsed while brushing with tap water (TWRB) (~22°) served as controls. Quality parameters were evaluated after 14 days storage at 12°C plus 3 days at 20°C as follows: Weight loss was measured by percentage of weight loss from the initial weight. Colour was measured on a Minolta Chroma-Meter (Minolta, Ramsey, NJ) that was calibrated with a white standard tile. Two sides of each tomato were measured and the results expressed as Hue angle ($\tan^{-b/a}$). Fruit firmness was measured using a Durometer (Shore Instrument and Mfg. Co., Jamaica, NY) on two sides of each fruit. Firmenss is expressed as units of firmness (UF). The higher the value the firmer the fruit. Total soluble solids (TSS) and titratable acidity (TA) were measured from juice prepared from frozen tissue. TSS was measured by a digital refractometer (Atago, Japan). TA was measured with aliquots (5 ml) of juice that were titrated to pH 8.1 with 0.1 N NaOH and the results expressed as percentage citric acid. Heat damage (flat pits of 0.5-1.5 mm in diameter) was determined visually and expressed as percentage of defective fruit. Decay incidence was expressed as percentage of fruits showing decay, and decay causing agents were identified. The experiment was repeated four times during 3 months, with 10 replicates per treatment.

Ethylene evolution and CO_2 production were measured during 14 days storage at 12°C plus 3 days at 20°C by placing one fruit in 0.5 L jar and closing the jar for 2 h each day. Each treatment consisted of 10 replicates. Headspace gases were sampled by syringe through a septum in the jar lid. The jars were left open and ventilated for 22 h between measurements. The experiment was conducted twice. Ethylene was measured with a gas chromatograph equipped with an FID detector and an alumina column held at 80°C with nitrogen as the carrier gas. Carbon dioxide was measured with a TCD detector with a Poropak N column held at 25°C and helium as the carrier gas.

Results were analyzed using Duncan's multiple range test at p=0.05. The angular transformation was applied before analysis of decay incidence.

Scanning electron microscopy (SEM) analysis

After 14 days storage at 12°C and 3 days at 20°C, pieces of skin about 1-2 mm^2 were excised from three untreated fruits and three fruits that were HWRB-52°C treated. Immediately after excising, samples were frozen by plunging into a copper block cooled by liquid nitrogen. The frozen samples were further dried by sublimation in a high vacuum device as described by Newbury *et al.* (1986) and were examined using a JEOL GSM-T300A scanning electron microscope at 10 kV, 0 and 30 degree tilt and 10 mm working distance. Samples were taken from two separate experiments for SEM analysis.

RESULTS

Quality parameters

After 14 days storage at 12°C plus 3 days at 20°C TWRB-treated fruits lost significantly more weight than fruits that were rinsed and brushed at 48 and 52°C. No significant differences in weight loss were observed between untreated control fruit and all other treatments except for TWRB-treated fruit (Table 1). The same results were observed in fruit firmness. Fruits rinsed and brushed at 52°C were found to be firmer than untreated or TWRB-treated fruit. No significant differences were observed in the amount of TSS and of citric acid amongst all treatments. In general, all heat treatments significantly delayed colour development compared with untreated fruit or fruit that were rinsed in tap water. The most pronounced colour inhibition was observed in HWRB-56°C treated fruit. A significant decrease in decay incidence was observed in HWRB-52°C treated fruit compared to all other treatments. A marked decrease in decay incidence was also observed in HWRB-48 and 56°C treated fruit (Table 1). *Botrytis cinerea* was identified as the main decay causing agent in all experiments. Heat damage was observed on the tomato skin that was rinsed at 56°C.

Respiration rate and ethylene evolution

During the storage period at 12°C, the respiration rate of HWRB-48 and 52°C treated fruit as measured by CO_2 production, was significantly lower than all other treatments (Figure 1A). Upon transferring the fruit to shelf life conditions (20°C), the respiration rates of fruit in all treatments dramatically increased, but the respiration rate of the HWRB-52°C remained significantly lower than that of all other treatments. The respiration rate of fruit that were rinsed in 56°C during shelf life was the highest amongst all other treatments (Figure 1A).

During the first 8 days in storage, the ethylene evolution of all treatments declined from the initial level, but the lowest ethylene evolution was measured for fruit rinsed and brushed in 52°C

Table 1: Quality parameters after 14 days storage at 12°C and 3 days at 20°C

Treatment	Weight Loss(%)[1]	Firmness (UF)[2]	TSS (%)[3]	TA (%)[4]	Colour (Hue°)	Decay (%)	Heat damage (%)
Untreated	3.2 ab[7]	32 b	4.4 a	0.7 a	37 c	18.5 a	0
TWRB[5]	3.5 a	31 b	4.4 a	0.7 a	37 c	7.0 b	0
HWRB[6]-48°C	3.0 b	33 ab	4.6 a	0.7 a	40 b	1.5 c	0
HWRB-52°C	2.8 b	35 a	4.7 a	0.8 a	41 b	0.3 d	0
HWRB-56°C	3.2 ab	33 ab	4.8 a	0.8 a	44 a	1.5 c	15

[1]Weight loss from initial
[2]Firmness- units of firmness 0-15=very soft; 16-30=soft; 31-45=firm; 45-60=very firm
[3]TSS-Total Soluble Solids
[4]T.A.-Percent of Citric Acid
[5]TWRB-Tap water rinsing and brushing (~22°C)
[6]HWRB-Hot Water Rinsing and Brushing for 15s.
[7]Values followed by the same letter are not significantly different at P=0.05 according to Duncan's multiple range test.

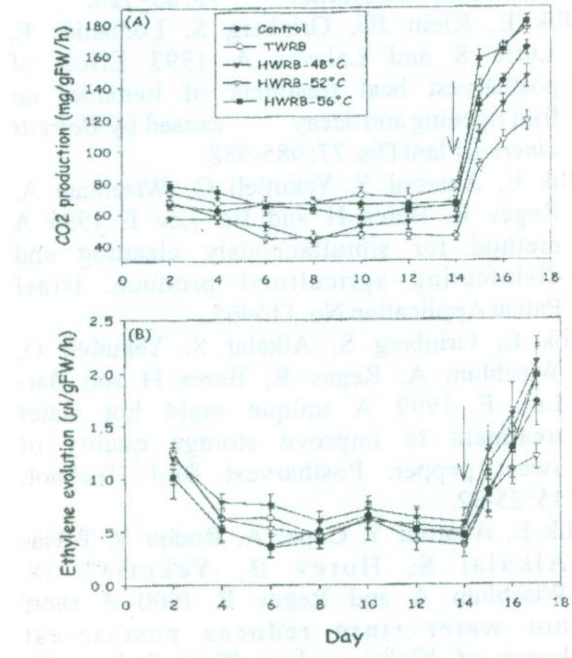

Fig. 1. CO_2 production (A) and ethylene evolution (B) of tomato fruit during 14 days at 12°C and an additional 3 days at 20°C as affected by HWRB treatments, compared with untreated control fruit or fruit that were rinsed and brushed in tap water (TWRB). Arrow indicates removal from 12°C to 20°C.

(Figure 1B). Upon transferring the fruit to 20°C. ethylene evolution increased in all treatments. although HWRB-52°C treated fruit increased less than the other treatments (Figure 1B).

SEM analysis

SEM analysis of the skin showed dirt particles, fungal spores of *Botrytis cinerea* and hyphae on the control fruit (Fig. 2A). The skin of hot water-rinsed (52°C) and brushed fruit was clean with no spores or dust particles on them (Fig. 2B). The wax plates were melted and recrystalized (Fig 2B).

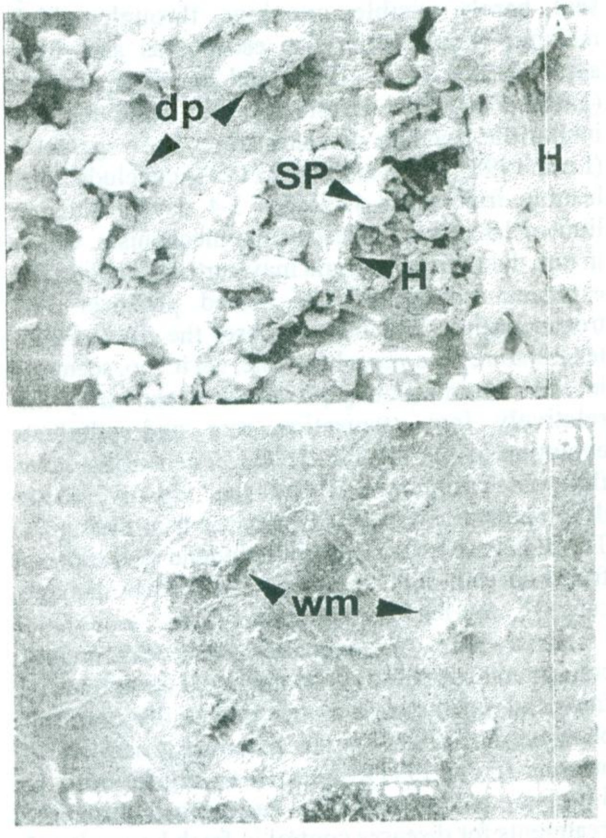

Fig. 2. Scanning electron microscopy of untreated skin (A) and rinsed and brushed skin at 52°C (B) (SP-*Botrytis* spores, H-hyphae, dp-dirt particles, wm-wax materials)

DISCUSSION

Several chemical-free technologies to extend the storage and shelf life of fresh produce are being investigated. A prestorage heat treatment appears to be one of the most promising in postharvest control of decay and inhibition of physiological disorders (Lurie 1998). The overall quality of pink tomatoes treated by HWRB at 52°C for 15 s was significantly better than that of untreated or TWRB treated fruit after a prolonged period of storage and marketing simulation for 3 days. The efficiency of HWRB treatment was dependent on the temperature used and time of exposure, as has been noted with peppers, grapefruits and mangoes (Fallik *et al.* 1999; Porat *et al.* 2000; Prusky *et al.* 1999). The lowered percentage of decayed fruit was due mainly to the combination of hot water rinse and brushing that removed dirt and spores from the peel (Figure 2B), as reported previously by Fallik *et al.* (2000) and Porat *et al.* (2000). HWRB-52°C treated fruits lost less weight and were firmer than untreated fruits. This may have been the result of recrystalisation or "melting" (Figure 2B) of the wax layer which may seal barely visible openings through which moisture would otherwise escape, as shown in apples (Lurie *et al.* 1996) and in sweet peppers (Fallik *et al.* 1999). Prestorage heat treatments can inhibit the ripening of many fruits and vegetables (Lurie 1998). Klein and Lurie (1991) concluded that heating fruit at 38-42°C for 3-4 days results in limited damage to the respiratory mechanism, which in turn delays ripening and may partially explain the extended storage life of heated produce. The treatment described here, exposes the fruit to high temperature for a very short time, yet it, too, seems to inhibit certain ripening processes as shown by the relatively low respiration rate and ethylene evolution of the HWRB-52°C treated fruit, by firmness retention and by the lag in colour development of the HWRB treated fruit (Table 1). The high respiration rate and ethylene evolution of fruit rinsed in 56°C might be due to heat damage caused by this high temperature.

In a time of increased awareness among consumers that many of the chemical treatments of fruits and vegetables to control insects, diseases, and physiological disorders are potentially harmful to humans (How 1991), there is an urgent need to develop effective, non-damaging physical treatments for diseases control in fresh horticultural products. This study has demonstrated that a combined treatment of a hot water rinse and brushing maintained better fruit quality over a prolonged period of storage and marketing. Therefore, this unique and fast technology would be desirable for the fresh harvested tomatoes.

ACKNOWLEDGMENTS

This research was supported in part by the EU/FAIR grant No. CT98-4211 and under grant No. 406-0813-00 from the Chief Scientist of the Ministry of Agriculture, Israel. Contribution from the Agricultural Research Organization, The Volcani Centre, Bet Dagan, Israel, No 424-00. We would like to thank Dr. Susan Lurie for her critical review, Mr. Irwin Fischer for the SEM preparation and photography and Mr. Michael Fallik for the graphic work.

REFERENCES

Barkai-Golan R 1973 Postharvest heat treatment to control *Alternaria tenuis* Auct. rot in tomato. Phytopath. Mediterr. 12:108-111.

Cuartero J and Fernandez-Munoz R 1999 Tomato and salinity. Sci.Hortic. 78: 83- 125.

Fallik E, Klein JD, Grinberg S, Lomaniec E, Lurie S and Lalazar A 1993 Effect of postharvest heat treatment of tomatoes on fruit ripening and decay caused by *Botrytis cinerea*. Plant Dis. 77: 985-988.

Fallik E, Aharoni Y, Yekutieli O, Wiseblum A, Regev R, Beres H and Bar-Lev E 1996 A method for simultaneously cleaning and disinfecting agricultural produce. Israel Patent Application No. 116965.

Fallik E, Grinberg S, Alkalai S, Yekutieli O, Wiseblum A, Regev R, Beres H and Bar-Lev E 1999 A unique rapid hot water treatment to improve storage quality of sweet pepper. Postharvest Biol. Technol. 15: 25-32.

Fallik E, Aharoni Y, Copel A, Rodov V, Tuvia-Alkalai S, Horev B, Yekutieli O, Wiseblum A and Regev R 2000 A short hot water rinse reduces postharvest losses of 'Galia' melon. Plant Pathol. 49: 333-338.

Hobson GE 1981 The short term storage of tomato fruit. J. Hortic. Sci. 56: 363-368.

How BR 1991 Marketing Fresh Fruits and Vegetables. AVI Book, Van Nostrand Reinhold, New York. 336 p.

Klein JD and Lurie S 1991 Postharvest heat treatment and fruit quality. Postharvest News Info. 2: 15-19.

Lichter A, Dvir O, Rot I, Akerman M, Regev R, Wiseblum A, Fallik E, Zauberman G and Fuchs Y 2000 Hot water brushing: an alternative method to SO_2 fumigation for color retention of litchi Fruits Postharvest Biol. Technol. 18: 235-244.

Lurie S 1998 Postharvest heat treatments of horticultural crops. Hort. Rev. 22: 91- 121.

Lurie S, Fallik E and Klein JD 1996 The effect of heat treatment on apple epicuticular wax and calcium uptake. Postharvest Biol. Technol. 8:271-277.

Newbury DE, Joy DC, Echlin P, Fiori CE and Goldstein JI 1986 (Eds) Advances in specimen preparation for biological SEM. In: Advances in Scanning Electron Microscopy and X-ray Microanalysis. New-York, Plenum Press, pp. 325-365.

Porat R, Daus A, Weiss B, Cohen L, Fallik E and Droby S 2000 Reduction of postharvest decay in organic citrus fruit by a short hot water brushing treatment. Postharvest Biol. Technol. 18: 151-157.

Prusky D, Fuchs Y, Kobiler I, Rot I, Weksler A, Shalom Y, Fallik E, Zaurberman G, Pesis E, Akerman M, Yekutieli O, Wiseblum A, Regev R and Artes L 1999 Effect of hot water brushing, prochloraz treatment and waxing on the incidence of black spot decay caused by *Alternaria alternata* in mango fruit. Postharvest Biol. Technol. 15: 165-174.