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Prevention of chilling injury in sweet bell pepper stored at 1.5ºC by heat treatments and individual shrink packaging

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ABSTRACT

The goal of this three-year study was to develop a quarantine-like treatment for two commercial sweet pepper (*Capsicum annuum* L.) cultivars, based on physical treatments and packaging materials, and to understand, in part, the chilling resistance-mode-of-action.

This research has revealed that individual shrink packaging following prestorage-HWRB treatment, significantly reduced chilling injuries and chilling severity, as shown by very low percentage of CI and a very low CI index, while maintaining a good overall quality (less decay incidence and weight loss) after 21 d at 1.5°C plus 3 d at 20°C (sea transport to USA and Japan from Israel + marketing simulation).

The chilling injury reduction is mainly due to a significant water loss reduction by the shrink film, while HWRB treatment contributed mainly to a significant decay reduction, and to some degree of inhibition of chilling development. Cultivar ‘Selika’ was found less susceptible to chilling then cultivar ‘7158’.

Abbreviations:

chilling index – CINX
chilling injury – CI
hot water rinsing and brushing – HWRB
hot water dip – HWD
shrink packaging – SP
tap water rinsing and brushing – TWRB.

INTRODUCTION

Sweet bell pepper (*Capsicum annuum* L.) is an important vegetable crop worldwide and can be consumed in many colours (Frank et al. 2001). Pepper is rich in vitamins, especially A and C, and is low in calories (Howard et al. 1994). The storage life of pepper fruit is limited by pathological deterioration (Ceponis et al. 1987), rapid water loss during prolonged storage (Diaz-Perez et al. 2007), and susceptibility to chilling injury (CI), which limits storage to temperatures above 7°C (Paull 1990). At temperatures below 7°C, within several days chilling injuries appear and are associated with severe pitting, weight loss, calyx darkening and decay development (Lim et al. 2007).

Cold-based quarantine treatments (exposure to 1.1-2.2°C for 14-18 d) (Palou et al. 2008), or heat-based quarantine treatments, commonly followed by cold storage to extend shelf-life (Neven 2003), against quarantine pests, such as the Mediterranean fruit fly *Ceratitis capitata* Wiedemann (*Diptera: Tephritidae*), must be currently applied to fresh fruits and vegetables exports to pest-free markets such as the United States or Japan. However, cold-based quarantine treatment is not feasible for bell peppers due to its susceptibility to chilling at temperatures below 7°C (Lim et al. 2007).

Several technologies have been reported to induce fresh produce tolerance to cold temperature and to reduce the development of CI symptoms during cold storage and cold quarantine treatments; postharvest heat treatments (Sapitnitskaya et al. 2006, Ghasernnezhad et al. 2008) and/or plastic materials (Kehr 2002, Kosson 2003).

The goal of this three-year study was to develop a quarantine-like treatment for sweet pepper based on physical treatments and packaging materials, and to understand, in part, the chilling resistance-mode-of-action.

MATERIAL AND METHODS

Plant material

Two red sweet bell pepper cultivars (*Capsicum annuum* L. 'Selika' and '7158'), of uniform size (about 190 ± 10 g each), without defects or diseases were harvested at 90% coloration, during the growing season from late December to April in 2005, 2006 and 2007, from the Arava valley in the south of Israel. Four harvests were conducted during each year.

Treatments and years of studies

The following treatments have been conducted:

1. TWRB – Fruits were rinsed over brushes with tap water (~22°C) for 15 s. This treatment served as control; 2005, 2006, 2007,
2. HWRB (commercial treatment) – Fruits were rinsed over brushes with hot water at 55°C for 15 s (Fallik et al. 1999); 2005, 2006, 2007,
3. HWD – Hot water dips at 52°C for 2 min; 2005,
4. Curing – Incubation at 44°C for 8.5h (US-APHIS, 1994/6); 2005,
5. HWRB + Curing – 6 h incubation at 38°C and 85% RH; 2006,
6. HWRB + SP – Individual shrink packaging (Cryovac® D-940, 19 μm thick, shrink tunnel oven temperature 170°C for 2-3 s); 2005, 2006, 2007,
7. TWRB + SP; 2007.

Quality traits

Fruit quality parameters were evaluated at the end of 21 day-storage at 1.5°C and relative humidity (RH) of 93% followed by 3 days at 20°C, RH 70% (marketing simulation). Weight loss was expressed as percentage of weight loss from the initial weight of ten fruits per carton. Fruit firmness was evaluated on ten fruit per carton by placing each fruit horizontally between two flat surfaces and 2 kg weight loaded (Fallik et al. 1999). Fruit was considered very firm with 0-1.5 mm residual deformation; firm = 1.6-3.0 mm deformation; soft = 3.1-4.5 mm deformation; very soft = more than 4.6 mm deformation. Fruit was considered decayed once fungal mycelia appeared on the peel or calyx. Decay was expressed as a percentage of the total initial fruit number. Chilling injury – a fruit with a sunken pitting of more than 2 mm on the skin or calyx was considered as a damaged fruit. CI was expressed as a percentage of damaged fruits from the total initial fruit number. The severity of the chilling injury was expressed as chilling index (CINX) – on a scale of 0 to 3 with 0 = no chilling injury; 1 = minor damage of less than 10% covering the fruit peel; 2 = moderate damage with 10 to 30% of damage covering the peel, and 3 = severe damage with more than 30% chilling damage. The index was calculated as follows: (number of fruits without damage X 0 + number of fruits with minor damage X 1 + number of fruits with moderate damage X 2 + number of fruits with severe index X 3) / total number of fruit.

Chilling injury development

The development of CINX was monitored for TWRB-treated fruit and HWRB-treated fruit stored 21 days at 1.5°C plus 3 days at 20°C. CINX was evaluated every 3 days and each treatment consisted of four boxes with 5 kg fruit. The results are shown for ‘Selika’ only as similar results were obtained also for cultivar ‘7158’. The experiment was repeated twice.

Statistical analysis

Four experiments were conducted each year, from late December to late March, once a month. Each treatment consisted of four export cartons with 5 kg fruit. Angular transformation was applied before the analysis of the incidence of decay. All data were subjected to one or two-way statistical analysis at p = 0.05 using JMP6 Statistical Analysis Software Program (SAS Institute Inc. Cary, NC., USA).

RESULTS

Chilling injury development

Chilling injury became visible at day 6, in both TWRB and HWRB (Fig. 1). Until day 15th, the CINX was similar. From day 15 and onward, CINX of HWRB-treated fruit increased more slowly than TWRB-treated fruit.

Quality evaluation

2005 – After 21 d at 1.5°C plus 3 d at 20°C, HWRB + shrink (SP) in both cultivars, significantly maintained fruit quality as shown by lower weight loss and firmer fruit, a relative low decay incidence, and low percentage of CI which was associated with a low CINX (Tab. 1). Except for HWRB + SP, all other treatments significantly lost more weigh and fruits were soft. TWRB-treated fruit and ‘curing’ had a significant higher decay incidence. The pepper cultivar ‘7158’ was found to be more susceptible to CI than ‘Selika’. Fruit kept at 44.5°C for 8 h (Curing) and fruit treated at 52°C for 2 min (HWD) suffered from severe heat damage (data not shown).

2006 – Based on the 2005 results, instead of 44.5°C for 8 h, fruit were kept at 38°C for 6 h (Curing) and HWD was omitted. In both cultivars, HWRB + SP significantly maintained fruit quality based on weight loss, firmness, decay incidence, CI and CINX (Tab. 2). Cultivar ‘7158’ was more susceptible to CI than ‘Selika’, however the chilling severity (CINX) was similar. The fruits treated with WRB and curing lost significant weight which also affected fruit firmness, and had a significantly higher decay incidence.

2007 – TWRB + SP and HWRB + SP-treated fruits, in both cultivars, had the lowest weight loss and firmer fruits after 21 d at 1.5°C plus 3 d at 20°C. These two treatments significantly reduced CI and CINX compared to the other treatments (Tab. 3). A high decay incidence was monitored in TWRB + SP-treated fruits, in both cultivars, while HWRB + SP-treated fruit had low to moderate decay incidence. Nonshrink-packed fruit of cultivar ‘7158’ was significantly more susceptible to CI, then ‘Selika’.

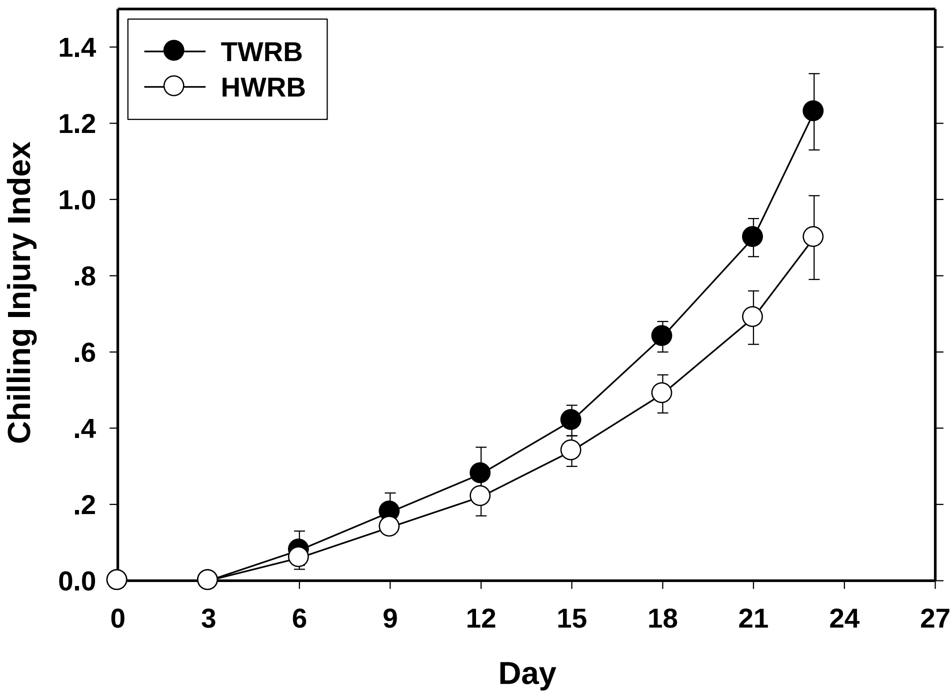

Figure 1. The effect of tap water rinsing and brushing (TWRB) and hot water rinsing and brushing (HWRB) on pepper ‘Selika’ chilling index during 21 day storage at 1.5°C + 3 days at 20°C

Table 1. The influence of various physical treatments in combination with shrink packaging, on fruit quality after 21 d storage at 1.5°C plus 3 d at 20°C in 2005, the results are the mean of 3 experiments

Treatment / Cultivar	Weight loss (%)		Firmness (mm deformation)		Decay (%)		CI (%)		CINX (3-0)	
	'Selika'	'7158'	'Selika'	'7158'	'Selika'	'7158'	'Selika'	'7158'	'Selika'	'7158'
TWRB	4.8 Ba*	4.4 Cb	3.4 Ca	3.3 Ca	11 Aa	10 Ba	15 Ab	20 Aa	1.1 Ab	1.3 Aa
HWRB	4.6 Ba	4.3 Ca	3.1 Ca	3.5 Cb	3 Ca	1 Db	5 Bb	10 Ba	0.6 Bb	0.9 Ba
HWD	5.6 Aa	5.4 Ba	3.8 Ba	3.9 Ba	7 Bb	10 Ba	15 Aa	15 Ba	1.0 Aa	1.2 Aa
Curing	6.0 Aa	6.1 Aa	4.3 Aa	4.4 Aa	13 Aa	13 Aa	7 Bb	11 Ca	0.6 Bb	0.9 Ba
HWRB + SP	0.3 Ca	0.4 Da	1.3 Da	1.2 Da	2 Ca	3 Da	1 Cb	4 Da	0.3 Ca	0.5 Ca

CI – chilling injury; CINX – chilling injury index; TWRB – tap water (~22°C) rinsing and brush; HWRB – hot water rinse and brush; HWD – hot water dip at 52°C for 2 min; Curing – 44.5°C for 8 h; SP – shrink packaging

*Values followed by the same upper-case letter do not significantly differ between the treatments, while values followed by the same lower-case letter, do not significantly differ between cultivars at $p = 0.05$ according to Duncan's multiple range test

Table 2. The influence of various physical treatments in combination with shrink packaging, on fruit quality after 21 d storage at 1.5°C plus 3 d at 20°C, in 2006, the results are the mean of 4 experiments

Treatment / Cultivar	Weight loss (%)		Firmness (mm deformation)		Decay (%)		CI (%)		CINX (3-0)	
	'Selika'	'7158'	'Selika'	'7158'	'Selika'	'7158'	'Selika'	'7158'	'Selika'	'7158'
TWRB	3.5 Aa*	3.3 Aa	3.1 Aa	3.3 Aa	11 Aa	8 Bb	20 Aa	26 Aa	0.9 Ab	1.3 Aa
HWRB	3.0 Ba	2.9 Ba	2.3 Bb	2.6 Ba	1 Ca	2 Ca	14 Bb	19 Ba	0.6 Bb	0.9 Ba
Curing	3.6 Aa	3.3 Ab	3.4 Aa	3.3 Aa	8 Bb	11 Aa	18 Aa	11 Cb	0.7 Ba	0.7 Ba
HWRB + SP	0.5 Ca	0.5 Ca	1.2 Ca	1.0 Cb	3 Ca	4 Ca	3 Cb	7 Da	0.2 Ca	0.4 Ca

CI – chilling injury; CINX – chilling injury index; TWRB – tap water (~22°C) rinsing and brush; HWRB – hot water rinse and brush; Curing – 38°C for 6 h; SP – shrink packaging
*Explanations: see Table 1

Table 3. The influence of various physical treatments in combination with shrink packaging, on fruit quality after 21 d storage at 1.5°C plus 3 d at 20°C, in 2007, the results are the mean of 4 experiments

Treatment / Cultivar	Weight loss (%)		Firmness (mm deformation)		Decay (%)		CI (%)		CINX (3-0)	
	'Selika'	'7158'	'Selika'	'7158'	'Selika'	'7158'	'Selika'	'7158'	'Selika'	'7158'
TWRB	4.3 Ab*	4.8 Aa	3.6 Ab	4.8 Aa	14 Bb	20 Aa	56 Ab	66 Aa	1.6 Ab	2.0 Aa
HWRB	4.4 Aa	4.7 Aa	3.3 Ab	4.8 Aa	4 Da	6 Ca	21 Bb	46 Ba	0.9 Bb	1.2 Ba
TWRB + SP	0.4 Bb	0.6 Ba	1.4 Ba	1.7 Ba	29 Ab	20 Aa	11 Ca	10 Ca	0.2 Ca	0.3 Ca
HWRB + SP	0.5 Bb	0.8 Ba	1.2 Ba	1.2 Ba	8 Cb	12 Ba	5 Db	8 Ca	0.1 Ca	0.3 Ca

CI – chilling injury; CINX – chilling injury index; TWRB – tap water (~22°C) rinsing and brush; HWRB – hot water rinse and brush; SP – shrink packaging
*Explanations: see Table 1

DISCUSSION

Our 3-year research has revealed that prestorage-HWRB treatment, in combination with individual shrink packaging, reduced almost totally chilling injuries, as shown by very low percentage of CI and a very low CI index, while maintaining a good overall quality after 21 d at 1.5°C plus 3 d at 20°C (sea transport to USA and Japan from Israel + marketing simulation).

HWRB was reported to reduce decay incidence and chilling injury in fresh produce although the fresh produce is exposed to the physical treatment for several seconds (Fallik 2004). Curing was also reported to control decay development and reduce fruit susceptibility to chilling injury (Erkan et al. 2005). However, curing the pepper fruit at 44.5°C for 8 h, as a quarantine treatment (APHIS, 1994/6), significantly damaged the fruit sink, which resulted in high decay incidence (Tab. 1). Therefore, the beneficiary effect of such treatment probably depends upon the crop and cultivar (Wurms 2005). Lim et al. (2007) reported that the development of chilling injury was highly correlated with water loss. Plastic materials are known to reduce water loss during prolonged storage (Aharoni et al. 2007). In addition, packaging materials were found to reduce chilling symptoms in pepper (Serrano et al. 1997), mango (Pesis et al. 2000), or lemon (Porat et al. 2004). The reduction in water loss by a shrink film, which serves as a tight barrier to water evaporation, plays an important key factor in reducing chilling stresses in fresh harvested produce. It is, therefore possible, that individual shrink packaging used here, inhibited fruit senescence by reducing water loss, which reduced fruit susceptibility to chilling. Hot water dips, in combination with shrink packaging reduced decay incidence and chilling injury in citrus fruit (Rodov et al. 2001). HWRB treatment mainly contributed to the significant decay reduction and very little to chilling reduction. Shrink packaging significantly inhibited chilling development while enhancing decay incidence (TWRB + SP – Tab. 3). However, once combining the two treatments (HWRB + SP), HWRB reduced decay development and maintained fruit quality, while shrink packaging reduced chilling injury and chilling severity due to significant reduction of water loss.

Other factors may affect fruit susceptibility to chilling. The susceptibility of fruit to CI is likely to be dependent on the cultivar and its genetic background as reported by Smith et al. (2006). ‘Selika’ was found less susceptible to chilling than ‘7158’.

CONCLUSIONS

Quarantine treatment for pest infestations of fruit commodities is needed for international trade (Follett and Neven 2006). Therefore, packing an appropriate cultivar of sweet pepper in shrink plastic film following HWRB treatment enables pepper's storage at 1.5°C for 3 weeks and can serve as a good quarantine treatment.

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OGRANICZANIE SZKODLIWOŚCI USZKODZEŃ CHŁODOWYCH OWOCÓW PAPRYKI SŁODKIEJ PRZECHOWYWANYCH W 1,5°C POPRZEZ ZASTOSOWANIE TRAKTOWANIA CIEPŁEM I INDYWIDUALNEGO PAKOWANIA W FOLIĘ KURCZLIWĄ

Streszczenie: Celem 3-letnich badań było uzyskanie metody podobnej w efekcie do traktowania kwarantannowego dla dwóch odmian papryki słodkiej (*Capsicum annuum* L.). Metody te wykorzystują właściwości materiału opakowaniowego oraz fizyczne podstawy traktowania ciepłem, stwarzają także szansę częściowego wyjaśnienia mechanizmów powstawania odporności na uszkodzenia chłodowe.

Badania wykazały, że indywidualne pakowanie w folię kurczliwą, przeprowadzane po traktowaniu HWRB poprzedzającym właściwy okres przechowywania, istotnie ograniczało uszkodzenia chłodowe i ich intensywność. Wykazano to poprzez niski udział procentowy uszkodzeń chodowych (CI) i niską wartość indeksu CI, jednocześnie zachowując ogólnie dobrą jakość (małe nasilenie gnicia i straty masy) po 21 dniach przechowywania w 1,5°C oraz dodatkowych 3 dniach w 20°C (odpowiadające transportowi morskiemu do USA i Japonii z Izraela plus symulowany okres obrotu).

Redukcja objawów uszkodzeń chłodowych była osiągana poprzez znaczące ograniczenie strat wody dzięki folii kurczliwej, podczas gdy traktowanie HWRB przyczyniało się głównie do znaczącego obniżenia gnicia oraz w pewnym zakresie powstrzymywania rozwoju uszkodzeń chłodowych. Odmiana 'Selika' była mniej podatna na uszkodzenia chodowe niż odmiana '7158'.

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