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HOT AIR AND SALICYLIC ACID POSTHARVEST TREATMENTS ALTERNATIVE TO FUNGICIDE IN NAVEL ORANGES DURING SHELF LIFE

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ABSTRACT

Navel oranges were treated either with hot air at 45 ºC for 30 min or dipped in salicylic acid solutions at 1000 and 2000 ppm concentrations for 15 min, whereas controlled fruits treated with 1400 ppm thiabendazol + 375 ppm imazalil fungicides. Fruits were held at 15 ± 2 ºC and 80-85 % RH for 4 weeks; simulating shelf life period to examine the potential use of hot air as an environmentally benign and or salicylic acid as a natural and safe phenolic compound for maintaining oranges quality characteristics of fruits during their shelf life period.

Salicylic acid at 2000 ppm showed the highest marketable fruit percentage and lowest decayed percentage, after 4 weeks of shelf life period, without significant difference comparing with fungicide treatment. Marketable fruit percentage was decreased, however decayed fruits were increased by advancing shelf life period and heat treatment applied. Soluble solid content: acid ratio was significantly increased by 32.71 and 31.25 % after 4 weeks compared with 2 weeks shelf life period, but it was significantly decreased by 20.64 and 14.76 % as affected by heat treatment. Salicylic acid at 2000 ppm significantly decreased soluble solid content: acid ratio as a result of maintaining titratable acidity values. Electrolytic leakage percentage of fruit's peel was significantly decreased as affected by prolonging shelf life period and heat treatment. Salicylic acid (1000 & 2000 ppm) did not reduce either spore germination or mycelial radial growth of *Penicilium Digitatum* Sacc in vitro compared with postharvest fungicides (thiabendazole and imazalil) treatment. However, salicylic acid had almost the same protective action against postharvest decay of Navel oranges caused by *Penicilium digitatum*.

Keywords: Navel oranges, postharvest treatment, salicylic acid, heat treatment, fruit quality, shelf life.

INTRODUCTION

Citrus industry considers to be pronounced, marked and technological competition among the leading export countries. It's obvious that fruit quality which includes nutritional content, flavor and appearance are being important for consumers. In addition, consumer demand is mainly focused on producing fruits free from both visible defects and chemicals residues that may be unhealthy. Up till now such chemicals have been widely employed in postharvest handling and cold storage of citrus fruits. Postharvest rot is the major factor limiting the extension of storage life of many freshly harvested fruit including Navel oranges, and there are very few registered, postharvest fungicides for control of decay-causing organisms. Fresh citrus fruit are susceptible to decay caused by fungi during the interval between harvest and the consumption. Green mold of citrus fruit, caused by *Penicillium digitatum* (Pres.: Fr.) Sacc., is the main wound pathogens of citrus fruit, causing the

most common and devastating postharvest diseases (Plaza *et al.,* 2004). Control of green mold traditionally has relied on sanitation, avoidance of fruit wounding, and use of preharvest and postharvest fungicides. *Penicillium digitatum*, however, frequently develops resistance to the commonly applied fungicides such as, benomyl, thiabendazole (TBZ) and imazalil (Eckert et al., 1994 and Wild, 1994). Some isolates of *P. digitatum* are resistant to both thiabendazole and imazalil (Bus, 1994; Bus *et al.,* 1991 and Holmes and Eckert, 1995). Additional control methods are subsequently needed for use in combination with, or without fungicides.

Although the use of synthetic fungicides is a most effective decay control treatment, there is a dire need to find another effective and safe non-fungicide means to control postharvest pathogens; because of the toxicity of the synthetic fungicide residues to the human health (Conway *et al.,* 2005 and Droby, 2006). Postharvest heat treatments have attracted research interest as a promising alternative method to replace or to reduce the use of toxic chemical during storage (Lurie, 1998 and Fallik, 2004). The beneficial effect of heat treatments on storability of different fruits is well documented. The exposure to temperatures higher than 35 ^{o}C has caused ripening inhibition in different fruits (Paull, 1990 and Lurie, 1998). Heat treatment of orange fruits at 44 or 46 ^{o}C appear to be an important commercial application and alternative to toxic chemical fumigants and approved disinfestations treatment as cold quarantine (Mario *et al.,* 2004). The effect of heat treatment on fungal decay may be due to a combination of direct inactivation of the pathogen and to the induction of some kind of natural resistance in the fruit (Fallik *et al*., 1995). Salicylic acid, a natural and safe phenolic compound, exhibits a high potential in controlling postharvest losses (Mesbah *et al*., 2007). Salicylic acid (SA), a simple ubiquitous plant phenolic, has been reported to regulate a number of processes in plants including reduced fruit ethylene production, fungal decay and retained overall quality (Zhang *et al.,* 2003 and Mesbah *et al*., 2007). In addition, as a hormone-like substance, salicylic acid has provide to be a major component in signal transduction pathways and plays an important role in the regulation of plant growth and development, including transpiration, stomatal closure (Ananieva *et al.,* 2004). It is believed that systemic acquired resistance is dependent on SA-mediated signaling and is associated with the production of proteins (Linda, 2001). In the field of disease control, SA has received particular attention because its accumulation is essential for expression of multiple modes of plant disease resistance. Exogenous application of SA at non-toxic concentrations to susceptible could enhance resistance to pathogens (Murphy *et a*l., 2000 and Galis *et al*., 2004).

The objectives of our studies aimed to evaluate the efficacy of hot air exposure, as an environmentally benign method, and salicylic acid, as antioxidant treatments in comparison with other chemical treatments currently used in citrus packinghouse to maintain higher marketable fruits and to determine the impacts of these treatments on Navel orange fruits quality during their shelf life (15 ^{o}C & 80-85 % RH) as stimulating marketing period.

MATERIALS AND METHODS

This work was carried out during two successive seasons (2005 & 2006). In March of both season, Navel orange fruits were obtained from the packinghouse line after washing and treating with 0.5 % sodium orthophenylphenol and finally air dried. The fruits were divided into two main groups. The first group was put in an air oven, set at 45 ^{o}C for 30 min, and then the fruits get out and held on the ambient temperature (15 ± 2 ^{o} C & 80-85 % RH). The second group was held on the ambient temperature without heat treatment. All of the fruits in both main groups were divided into three subgroups. One third of the three subgroups were dipped in 1400 ppm thiabendazol (TBZ) + 375 ppm imazalil (IMZ), as a control treatment for packinghouse, the second third subgroup was dipped in 1000 ppm salicylic acid (dissolved in 0.5 % ethyl alcohol) and the last third subgroup was dipped in 2000 ppm salicylic acid for 15 min for each. Every treatment was represented by three replicates with eight orange fruits for each. After treatments, the fruits were held at ambient temperature (15 ± 2 ^{o} C & 80-85 % RH), simulated retail shelf life condition, for 4 weeks period. Half of the treated fruits were taken out after 2 weeks and the second half were taken out after 4 weeks, to evaluate the fruit quality parameters. Marketable fruits were recorded and expressed as percentage of sound fruits, without any defect, related to the initial fresh weight before the treatment. Four fruits for every treatment in each replication were juiced to determine: soluble solid content (SSC), using hand refractometer (ATAGON-1-E), titratable acidity (TA) as citric acid percentage by titrating against 0.1 N NaOH. SSC: acid ratio was calculated. Ascorbic acid was determined by using titermetric method and 2, 6 diclorophenolindophenol dye. The rate of electrolyte leakage of peel tissue excised from two fruits per replication for each treatment was determined (Schirra and D'hallewin, 1997) and then expressed as a percentage.

An informal panel of untrained assessors evaluated the fruit segments samples. The evaluation based on degree of acceptability of fruit freshness and taste of the fruit segments by using a scale ranging as follow: freshness (5, excellent; 4, fresh; 3, acceptable; 2, welt; 1, severe welt). Taste evaluation was scored on a 10- point scale (0 very bad; 5, acceptable for commercial purpose; and 9, excellent).

Pathogen, salicylic acid and fungicides:

A *Penicilium digitatum* isolate used in these tests was isolated from naturally infected citrus fruits. The culture was initiated by using cultures of a single spore. The pathogen was maintained in potato dextrose agar (PDA) slants in test tubes stored at 4°C. The pathogenicity and virulence were tested on citrus fruits. Salicylic acid (El Gomhoria Company) and commercially citrus postharvest fungicides; thiabendazol (45% w/v) and imazalil (70% w/v) were used.

Spore suspension preparation of *P. digitatum*:

Prior to each, *P. digitatum* was recovered from PDA slants in storage and grown in 9-cm plates with PDA at 25°C for 7 to 10 days. Spores were

harvested from a PDA plate by adding about 8 ml of sterile water with 0.05% Triton X-100 and rubbing the fungal colony with a sterile glass rod. The spore suspension was filtered through two layers of sterile cheesecloth to remove the mycelia and medium particles, and diluted with sterile water to an absorbance of 0.1 at 420 nm using a spectrophotometer. This density of the spore suspension was equivalent to a concentration of approximately 10^6 spores per ml (Smilanick et al., 1999). The spore concentration was confirmed using a hemacytometer to determine actual spore counts of the suspension.

Natural injury and infection:

Navel orange fruits which naturally infected by *P. digitatum*, whereas injuries resulted from harvest and subsequent postharvest handling procedures, were used in this study.

In vitro antimicrobial activity assays:

a) Germinability of spores

To determine the effect of SA or commercial control (1400 ppmTBZ + 375 ppm IMZ) treatments on spores germinability of *P. digitatum*, 1 ml from fresh spore suspension containing 1 X 10^6 spores / ml was added to 9 ml of distilled water alone (absolute control) or solutions from each of SA (1000 or 2000 ppm) or fungicide control (1400 ppm TBZ + 375 ppm IMZ) and incubated at 25 °C for 10 h. The proportion of germinated spores was determined by examination of 100 spores by light microscope at 100 X magnification. Each treatment was carried out as three replicates sample.

b) Effect on fungal radial growth:

To determine the effect of SA or TBZ + IMZ of the radial growth of *P. digitatum*, trials were performed using PDA medium amended with a SA or fungicide. A 10 µl drop of fresh spore suspension, containing 10^6 spores per ml was placed on the center of plates of potato dextrose agar (PDA) amended with SA or TBZ + IMZ at the same concentrations mentioned previously, and on unamended PDA (absolute control). In each case, grade material was dissolved and added to autoclaved, cooled, PDA. The test was performed three times; each trial included 3 plates of each treatment. Plates were incubated at 25 ºC and colony diameter was recorded 5 d after transferring spore suspensions to the plates.

The experimental design was randomized complete block design with factorial arrangement of treatments (Byrkit, 1987). A group of three replicates of 8 fruits per treatment was used. Data in percentage was transformed to the arcsine of the square root. The data was analyzed by "ANOVA" and the significance among treatment means values were determined by Duncan's multiple range test (DMRT) at probability level 0.05.

RESULTS AND DISCUSSION

Marketable fruits (MF), as shown in Table 1& Fig. 1a, were slightly decreased by progressing shelf life period and heat treatment application as a result of accelerate the fruit weight loss, mainly due to the elevated transpiration rate at the higher temperature and longer shelf life period.

Increases in decayed fruit percentage (Table, 1 & Fig. 1b) were detected as a result of hot air treatment. These results are contrary to the findings of Mario *et al*., (2004) on "Blood oranges"; and Seok et al., (2007) on "Satsuma" mandarin and this might be due to use of either hot water, as a source of heat treatment instead of hot air, or shorter exposure time. After 2 weeks shelf life period, control treatment with fungicide showed the highest marketable fruit percentage (MF) (93.00 & 90.18 %) and the lowest decayed fruit percentage (DF) (3.41 & 2.89 %) in the two seasons, respectively. However, after 4 weeks, Salicylic acid treatment at 2000 ppm showed the highest MF (87.45 & 86.36 %) and the lowest DF (3.21 & 3.88 %) without significant difference compared to fungicide treatment in the two seasons, respectively. The inhibitory effects of fruit postharvest treatment with SA on fungal decay confirm the previous reports about its antifungal effects (Cai and Zheng, 1999; Amborabe *et al*., 2002 and Lu and Chen, 2005). SA increases activation of peroxidase. Peroxidases represent a component of an early response system may formed in plant to face pathogen attack, which are usually associated with plant defense mechanisms such as lignification and suberization of cell wall forming mechanical barrier substances which limit extent of pathogen spread and generation of hydrogen peroxides or other free radicals which exhibit antimicrobial effects (Tuzun, 2001 and Passardi *et al*., 2004).

It could be observed in Table, 1 that with prolonging shelf life period a significant decrease in electrolytic leakage by 21.30 and 20.66 % after 4 weeks comparing with 2 weeks was observed in the two seasons, respectively. Heat treatment also appears to decrease electrolytic leakage by 4.07 and 4.14 % comparing with non heated-fruit in the two seasons, respectively. These results might due to the integrity of fruit membrane components (plasmalemma and / or tonoplast) which responded by heat treatment (Ariel et al., 2006). The present data revealed that there was no significant difference between salicylic acid and fungicide treatments.

Natural injury and infection:

Effect of SA and postharvest fungicides on natural injury and fungal infections (decayed fruits) is indicated in Table (1).

Toxicity to spores In Vitro and Effect on fungal radial growth:

Data in Table, 2 shows that SA treatment, at both concentrations, had slight effect on reducing spore germination and linear growth; however fungicides treatment was highly effective in inhibiting of spores germination and linear growth of *P. digitatum* on potato dextrose agar. Salicylic acid (1000 & 2000 ppm) was not able to reduce either spore germination or mycelial radial growth of *P. digitatum* in vitro compared with postharvest fungicides (thiabendazole and imazalil) treatment.

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Table, 2: Effect of salicylic acid (SA) and thiabendazole (TBZ) + imazalil (IMZ) on the germinability of spores, linear growth (cm) and reduction of colony diameter of *Penicillium digitatum*

Treatment	Germination Of *P. digitatum* conidia *(%)*	L.G. (cm)	R. (%)
Control (1400 ppmTBZ+ 375 ppm IMZ)	13 c	0.60 c	93.33 a
Salicylic acid (1000 ppm)	85 b	7.12 b	20.88 b
Salicylic acid (2000 ppm)	78 b	6.85 b	23.89 b
unamended PDA (absolute control)	100 a	9.00 a	0.00 c

L.G. = fungal linear growth (cm), R. = % reduction of colony diameter. Means followed by the same letter are not significantly different at the level of 5 % according to DMRT. Each value is the mean of three replicates.

However, SA had almost the similar protective action against postharvest decay of Navel oranges caused by *P. digitatum*. This conclusion suggests that, application of SA induced some defense mechanism within the fruit or a pathogenicity strategy of the fungus, during infection of Navel oranges by *P. digitatum*. These results are consistent with those obtained by Ballester *et al*., (2006) which indicated that some antioxidant enzymes may play a role in the defense response of citrus fruit against *P. digitatum* invasion and especially in the resistance of flavedo tissue to infection of this fungus.

Ascorbic acid content (Table, 3) was increased with advancing shelf life period and applying hot air treatments. However, salicylic acid treatment did not significantly reduce ascorbic acid content compared to fungicide treatment. Fruit freshness (Table, 3) was decreased as the shelf life period prolonged and fruits applied with heat treatment, especially in the second season, which may be attribute to fruit transpiration (Seok *et al.,* 2007). However, salicylic acid at 2000 ppm treatment maintained the fruit freshness comparing with fungicide treatment.

Fruit segments taste, as shown in Table 3, was decreased by 8.67 and 17.60 % as affected by heat treatment comparing with non heated-fruit; however it showed in significant difference after 4 weeks compared to 2 weeks shelf life period in both seasons, respectively. The heat-treated fruit showed lower taste score. These results supported previous findings of Schirra *et al.,* (2002) on "Tarocco" oranges and Mario *et al.,* (2004) on "Blood" oranges. It could be also observed that salicylic acid treatment decreased fruit taste especially in the second season. The lower taste score might due to other components as ethanol accumulated in fruit, which contribute negatively on organoleptic characteristics (Moshonas and Shaw, 1997).

Soluble solid content (SSC) did not show significant difference as affected by heat and SA treatments; however it showed different trends in two studied seasons as affected by shelf life period. Titratable acidity (TA) was significantly decreased by 25.68 and 27.63 % after 4 weeks compared with 2 weeks of shelf life period, while it was increased by 32.14 and 27.58 % as affected by hot air treatment compared with non heated-fruit in the two seasons, respectively (Table, 4 & Fig. 1 c). Heat treatment disrupts ripening and inhibits ethylene formation. Although this inhibition of ethylene synthesis is usually reversible, the recovery requires protein synthesis (Paull, 1990). The obtained data showed that salicylic acid treatment maintained titratable acidity content at higher levels; however control (fungicide) treatment significantly decreased titratable acidity content. SSC: acid ratio (Table, 4 & Fig. 1d) was significantly increased by 32.71 and 31.25 % after 4 weeks compared with 2 weeks shelf life period, however it was significantly decreased by 20.64 and 14.76 % with hot air treatment compared with non heated-fruit in two seasons, respectively. The present data revealed that SSC: acid ratio might be depend on TA ($r = - 0.919$ $P = 0.000$) more than SSC ($r = 0.340$ $P=0.000$). Salicylic acid treatment at 2000 ppm decreased SSC: acid ratio by 22.44 and 16.8 0 % comparing with fungicide treated-fruit, in the two seasons, respectively. These results might be due to that SA decrease ethylene production leading to noticeable decrease in metabolic activity almost including respiration. Decrease in fruit metabolic activities eventually delays fruit senescence process (Wills *et al*., 1998; Wolucks *et al.,* 2005 and Mesbah et al., 2007).

In conclusion, in the present work the treatment of 2000 ppm salicylic acid postharvest application have the apparent effect than fungicide on maintenance of marketable fruits and decrease decayed fruit percentages, and may be applied as alternative to thiabendazol and imazalil fungicides treatment to maintain Navel oranges for more than two weeks in shelf life. However, treatment by hot air at 45 ^{o}C for 30 min increased fruit weight loss, decayed fruit, decreased marketable fruit, lowered fruit freshness, fruit segment taste scores, and increased titratable acidity, and could not recommended to Navel oranges. Further studies are being needed for using other antioxidant to induce a systemic acquired resistance, overcome the low fruit segment taste score and apply other heat treatment.

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معاملات مابعد الحصاد بالهواء الساخن وحامض السلسيليك كبديل للمبيدات الفطرية للبرتقال بسرة اثناء حياة الرف

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اجريت هذه الدراسة خلال موسمين متتاليين (2005 & 2006) حيث عوملت ثمار برتقال بسرة بواسط الهواء الساخن (45 درجة مئوية لمدة 30 دقيقة) و / أو عوملت الثمار بالنقع في حامض الساسيليك (1000 & 2000 جزء في المليون) لمدة 15 دقيقة في حين تمت معاملة ثمار الكنترول بواسطة المبيد الفطري ثيابندازول (1400 حزء في المليون + 375 جزء في المليون إيمازاليل) ثم تم وضع الثمار على درجة حرارة الغرفة (15 درجة مئوية & 80 – 85 % رطوبة نسبية) لمدة أسبوعين وذلك لإختبار مدى إمكانية استخدام الهواء الساخن و/ أو حامض السلسيليك وذلك للحفاظ على صفات الجودة لثمارالبرتقال بسرة أثناء حياة الرف. وقد أظهرت الدراسة أن المعاملة بحامض السلسيليك بتركيز 2000 جزء في المليون قد اعطت أعلى نسبة مئوية للثمار القابلة للتسويق وأقل نسبة من الثمار التالفة وذلك بدون اختلاف معنوي بالمقارنة بمعاملة المبيدات الفطرية وذلك عند 4 أسابيع من حياة الرف. هذا وقد إنخفظت النسبة المئوية للثمار القابلة للتسويق بينما إرتفعت نسية الثمار التالفة وذلك بزيادة طول فترة حياة الرف وكذلك باستخدام معاملة الهواء الساخن. وقد ازدادت نسبة المواد الصلبة الذائبة الكلية : الحموضة زيادة معنوية ينسبة 32.71 & 31.20% في موسمي الدراسة على التوالي يعد 4 أسابيع مقارنتاً باسبوعين من حياة الرف بينما انخقصت نسبة المواد الصلبة : الحموضة انخفاضاً معنوياً بنسبة 20.64 & 14.76 % نتيجة المعاملة بالهواء الساخن في موسمي الدراسة, هذا وقد أدت المعاملة بـ 2000 جزء في المليون حامض سلسيليك الى الإنخفاض المعنوي لتلك النسبة ايضاً. كما لوحظ أنخفاضاً معنويا في التوصيل الكهربائي لقشرة ثمار برتقال بسرة وذلك نتيجة لزيادة طول فترة حياة الرف وكذلك المعاملة بالهواء الساخن.

اظهرت النتائج ان المعاملة بحمض السلسيليك بكل من التركيزين (1000 & 2000 جزء في المايون) كان ذات تأثير منخفض جداً على كل من تثبيط انبات الجراثيم الكونيدية وكذا على تثبيط النمو القطري لفطر بنسليوم ديجيتاتم النامية في اطباق بتري وذلك مقارنتاً بالتأثير المثبط للمبيدات الفطرية المستخدمة. وعلى الجانب الآخر فان حامض السلسيليك كان له نفس التأثير تقريباً مقارنتاً بالمبيدات الفطرية المستخدمة في حفظ ثمار البرتقال بسرة ضد العفن بعد الحصاد والمتسبب من البتسليوم ديجيتاتم.

Table, 1: Effect of hot air, salicylic acid treatments and shelf life period on marketable, decayed fruits percentages and fruit peel electrolytic leakage of Navel oranges

e period(P)	Marketable fruits (%)				Decayed fruits (%)				Electrolytic leakage (%)			
	Season 2005		Season 2006		Season 2005		Season 2006		Season 2005		Season 2006	
	Two weeks	Four weeks	Two weeks	Four weeks	Two weeks	Four weeks	Two weeks	Four weeks	Two weeks	Four weeks	Two weeks	Four weeks
(H) Non heated treatment												
ntrol @	93.00 a	90.82 a	90.18 a	84.26 b	3.41 b	5.61 a	2.89 a	5.90 a	64.77 a	45.99 a	65.95 a	50.11 a
00 ppm	87.46 b	82.94b	89.95 a	88.81 a	3. 46 b	4.21 ab	3.17 a	3.43 ab	68.50 a	53.12 a	72.31 a	47.13 a
0 ppm	84.58 c	86.23b	87.92 a	88.07 a	7.27 a	3.46 b	5.20 a	2.86 b	67.61 a	50.43 a	72.49 a	52.73 a
t mean	88.60AB	87.98B	89.37A	87.11B	4.60 B	4.38 B	3.69 A	3.97 A	66.97 A	49.85C	70.29A	58.30B
(H) Hot air treatment at 45 ºC/ 30 min												
	92.72 a	86.52 a	88.17 a	84.03 a	5.28 a	5.81 a	4.40 b	6.67 a	58.70 a	55.68 a	57.93 a	53.87 a
0 ppm	85.54 c	86.55 a	85.15 a	85.88 a	6.60 a	7.21 a	7.55 a	3.69 b	59.24 a	53.06 a	54.13 a	51.59 a
0 ppm	88.25 b	87.45 a	85.69 a	86.36 a	7.58 a	3.21 a	5.55 ab	3.88 b	62.92 a	46.57 a	62.78 a	50.48 a
tment mean	89.20A	86.84C	86.37C	85.44C	6.45 A	5.28 B	5.76 A	4.66 A	60.29 B	51.78	49.99C	51.98C
eriod mean	**88.59**	**87.98**	**87.87**	**86.27**	**5.62**	**4.92**	**4.71**	**4.40**	**63.66**	**50.81**	**64.26**	**50.99**
	**		NS		NS		NS		**		**	
	NS		**		**		*		NS		*	
	**		NS		*		NS		NS		NS	
	**		**		**		**		NS		NS	
	*		*		*		NS		*		**	
P	*		NS		NS		NS		NS		NS	

@ **Fungicides (1400 ppm thiabendazol + 375 ppm imazalil), • salicylic acid. In the same cell, means followed by the same letter are not significantly different at the level of 5% according to DMRT.**

Table, 3: Effect of hot air, salicylic acid treatments and shelf life period on ascorbic acid content and sensory evaluation of Navel oranges

Shelf life period(P) / Treatments	Ascorbic acid (mg/100ml juice)				Fruit freshness (1-5) [y]				Fruit segments taste (0-9) [z]			
	Season 2005		Season 2006		Season 2005		Season 2006		Season 2005		Season 2006	
	Two weeks	Four weeks	Two weeks	Four weeks	Two weeks	Four weeks	Two weeks	Four weeks	Two weeks	Four weeks	Two weeks	Fou wee
(H) Non heated treatment												
(S) Control @	44.85 a	44.38 a	44.57 a	41.34 a	3.25 a	3.08 a	3.67 a	4.00 a	6.17 a	5.67 a	5.83 a	5.33
● SA 1000 ppm	41.2 1a	43.89 a	44.66a	42.37 a	3.58 a	3.00 a	3.25 b	3.08 b	6.17 a	4.83 b	6.00 a	3.42
SA 2000 ppm	45.24 a	40.66 a	43.13 a	43.32 a	2.75 b	3.00 a	3.17 b	3.33 b	4.75 a	3.42 c	6.17 a	4.42
Air treatment mean	43.77A	42.98A	44.12BC	42.34C	3.19 A	3.02 A	3.36 A	3.47 A	5.69 A	4.64 B	6.00 A	4.19
(H) Hot air treatment at 45 ºC/ 30 min												
Control	47.73 a	43.89 b	50.60a	49.59a	3.17 a	2.75 b	3.92 a	2.58 b	5.00 a	3.08 b	5.33 a	4.42
SA 1000 ppm	47.54 a	51.58 a	46.20 a	55.10 a	2.92 a	2.83 b	3.33 b	2.42 b	4.83 a	3.92 a	4.67 a	4.83
SA 2000 ppm	47.34 a	51.11 a	45.43 a	49.59a	3.11 a	3.33 a	3.33 b	3.08 a	4.50 a	4.25 a	4.83 a	4.33
Hot air treatment mean	47.54 A	48.89 A	47.41AB	51.43 A	3.03 A	2.97 A	3.53 A	2.69 B	4.78 B	3.75 C	4.94 B	4.53
Shelf life period mean	**45.65**	**45.94**	**45.78**	**48.61**	**3.11**	**3.00**	**3.44**	**3.08**	**5.24**	**4.19**	**5.47**	**4.4**
P	NS		NS		**		NS		**		**	
H	**		*		**		NS		*		**	
S x H	NS		NS		**		*		**		NS	
S x P	NS		NS		**		*		NS		NS	
H x P	NS		*		NS		**		*		**	
S x H x P	NS		NS		NS		**		**		**	

@ Fungicides (1400 ppm thiabendazol + 375 ppm imazalil), ● salicylic acid; Y fruit freshness (5, excellent; 4, fresh; 3, acceptable; 2, welt; 1, severe welt). z Taste evaluation was scored on a 10- point scale (0 very bad; 5, acceptable for commercial; purpose; and 9, excellent). In the same cell, means followed by the same letter are not significantly different at the level of 5% according to DMRT.

Table, 4: Effect of hot air, salicylic acid treatments and shelf life period on some quality indices of Navel oranges

fe period(P)	SSC (%)				Titratable acidity (%)				SSC/acid ratio			
	Season 2005		Season 2006		Season 2005		Season 2006		Season 2005		Season 2006	
	Two weeks	Four weeks	Two weeks	Four weeks	Two weeks	Four weeks	Two weeks	Four weeks	Two weeks	Four weeks	Two weeks	Four weeks
(H) Non heated treatment												
ontrol @	13.87 a	15.10 a	14.53 a	14.00 a	0.58 b	0.48 b	0.65 a	0.57 a	26.42 a	31.41 a	22.25 a	24.53b
1000 ppm	14.00 a	14.40 a	14.13 a	14.93 a	0.61 a	0.53 ab	0.66 a	0.53 a	23.01b	27.00b	21.59 a	27.89 a
00 ppm	13.40 a	14.80 a	14.00 a	14.73 a	0.63 a	0.58 a	0.58 a	0.52 a	21.45b	25.41b	24.09 a	28.21 a

tment mean	13.76 B	14.77A	14.22 B	14.59AB	0.59 B	0.53 B	0.63 B	0.54 C	23.63 B	27.94 A	22.65 B	26.88 A
(H) Hot air treatment at 45 ºC/ 30 min												
l	14.33 a	14.40 a	14.53 a	14.61 a	0.66 b	0.55 b	0.65 b	0.62 a	21.97a	26.23 a	22.35 a	24.26 a
00 ppm	13.80 a	14.27 a	15.47 a	14.29 a	1.03 a	0.55 b	1.04 a	0.55 a	13.34b	25.83 a	14.89b	26.03 a
00 ppm	13.67 a	14.10 a	14.60 a	13.73 a	1.05 a	0.63 a	1.05 a	0.54 a	13.03b	22.35b	13.88b	25.35 a
tment mean	13.93 B	14.26AB	14.86A	14.21 B	0.90 A	0.58 B	0.91 A	0.57 C	16.12 C	24.80 A	17.04 C	25.21 A
eriod mean	**13.84**	**14.51**	**14.54**	**14.40**	**0.75**	**0.55**	**0.77**	**0.56**	**19.87**	**26.37**	**19.84**	**26.04**
	*		NS		**		**		**		**	
	NS		NS		**		**		**		**	
	NS		NS		**		**		**		NS	
	NS		NS		**		**		**		NS	
	*		*		**		**		*		*	
P	NS		NS		**		**		NS		NS	

[@] Fungicides (1400 ppm thiabendazol + 375 ppm imazalil), • salicylic acid. In the same cell, means followed by the same letter are not significantly different at the level of 5% according to DMRT.

2075
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