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Effect of Jojoba Oil and Boric Acid as Postharvest Treatments on the Shelf Life of Washington Navel Orange Fruits

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ABSTRACT

This study intended to revise the effect of postharvest dipping in boric acid and/or jojoba oil alone on quality of Washington Navel orange fruits through marketing period at 18°C. The experiments were carried out during 2011 and 2012 seasons. Results showed that all dipping treatments of orange increased fruit quality when compared with the control. Boric acid (1.0%)+jojoba oil (0.1%) treatment gave maximum reduction in linear growth and dry weight of *Penicillium digitatum* and *P. itelicum*, as well as disease infection (0.0%) caused by both fungi in the two seasons. The same treatment decreased weight losses percentage, fruit decay, total losses in fruit, titratable acidity and ascorbic acid oxidase. On the other hand, increased soluble solids, SSC/acid ratio, ascorbic acid content, peel thickness and juice percent. The recommendation of this study, the combination treatment of boric acid (1.0%) plus Jojoba oil (0.1%) was the most effective treatment in decreasing disease infection percentage of the tested pathogenic fungi as well as weight losses, fruit decay, total loses in fruit, titratable acidity and ascorbic acid oxidase. However, increasing the quality of fruits was reported by such treatment.

Key words: Washington Navel orange, shelf life, boric acid, jojoba oil, green mould, blue mould

INTRODUCTION

Citrus species are major exports products of Egypt. The total cultivated area for citrus fruits are 159,446,143 ha with total production estimated to 3,311,300 ton (FAO, 2010). The orange cultivation accounts 63% of Egypt's total citrus production. Three main varieties of oranges are produced in Egypt: Navel, Valencia and Baladi. Washington Navel orange (*Citrus sinensis*, L. Osbeck) is the most popular orange cultivar among other citrus species in Egypt.

Green and blue moulds, caused by *Penicillium digitatum* (Pers.Fr.) Sacc. and *Penicillium italicum* Wehmer, respectively, are the most significant postharvest diseases of citrus in all production areas that like Spain, California or Israel (Eckert and Eaks, 1989).

Both *P. digitatum* and *P. italicum* are severe wound pathogens that can infect the fruit in the orchard, the packinghouse and during allocation and marketing. They reproduce very quickly and their spores are ubiquitous in the atmosphere and on fruit exterior and are simple distributed by air currents. Therefore, the source of fungal inoculum in citrus orchards and packing houses is virtually continuous during the season (Kanetis *et al.*, 2007). Citrus fruit can become "soiled" with conidia of the two fungi that are loosened in handling of diseased fruit. The conidia located in damage that laceration oil glands or penetrate into the albedo of the peel usually bring irreversible infection within 48 h at 20-25°C (Eckert and Eaks, 1989). The germination of conidia of both *Penicillium* species inside rind wounds requires free water and nutrients (Plaza *et al.*, 2003; Lahlali *et al.*, 2006; Stange *et al.*, 2002).

Postharvest diseases caused by *Geotricum candidum* (sour rot), *Penicillium digitatum* (green mould) and *P. italicum* (blue mould) are the very significant negative agents affecting in handling and marketing of citrus fruits in Egypt (El-Mougy *et al.*, 2008). They cause dangerous problems to the harvested citrus fruits during handling, transportation, exportation and the storage process. Although the use of chemical fungicides gave satisfactory control against mould infection, the fungicide residual can have a harmful effect on people and the environment.

Moreover, successive use of fungicides could lead to some fungal isolates to develop a significant resistance to the applied fungicides. Therefore, alternative fungicide treatments are needed for the management of postharvest diseases of citrus fruits.

Qin *et al.* (2010) revealed that boron strongly inhibited spore germination, germ tube elongation and mycelial spread of *Botrytis cinerea* in the culture medium. Moreover, application of boron at 1% caused the appearance of abnormal spores (disrupted) in some cases. Furthermore, boron led to the leakage of cellular constituents (soluble proteins and carbohydrates) from hyphae of *B. cinerea*. The quantities of boric acid and its sodium salts applied as pesticides are modest compared to amounts used for the other non-pesticidal purposes. Further, boric acid, borax and boron-containing salts are ubiquitous in the environment. Boron occurs naturally in water, fruits, forage crops and is an essential nutrient for plants as well as an essential element for many organisms.

The mechanisms by which boron decreased gray mold decay, may be directly related to the disruption effect of boron on cell membrane of the fungal pathogen that resulted in the breakdown of the cell membrane and loss of cytoplasmic materials from the hyphae. Exogenous application of boron was shown to alleviate the occurrence of browning injuries in pears during controlled atmosphere storage (Xuan *et al.*, 2005). Nevertheless, little information is available concerning the effect of boron for control of plant disease caused by microbial pathogens and the physiological basis involved. The inhibition effect of *P. expansum* may be related to the increased oxidative stress caused by boron through suppressing the expression of antioxidant enzymes in the pathogen (Qin *et al.*, 2007).

Jojoba oil is commonly known as liquid wax, colorless and odorless with unique physical and chemical properties. Also, jojoba oil can easily be hydrogenated into a soft wax that can be used in candle wax, various kinds of polishes, coating material for fruits and pills (Nagvi and Ting, 1990). Abd El-Moneim and Abd El-Mageed (2006) revealed that coating Washington Navel orange fruits with jojoba oil led to reduce fruit decay, weight loss and increasing fruits storage life. As storage days progressed total soluble sugar (TSS) increased, but the titratable acidity and ascorbic acid contents decreased. Abd-Allah *et al.* (2012) found that coating persimmon fruits with jojoba oil helped to delay ripening and reduced weight loss and decay percentage.

The purpose of this study was to investigate the dipping affection boric acid and/or jojoba oil on controlling postharvest diseases caused *Penicillium digitatum* (green mould) and *P. italicum* (blue mould) to improve fruit quality during marketing period.

MATERIALS AND METHODS

This investigation was carried out for two successive seasons (2011 and 2012) to evaluate the effect of jojoba oil and boric acid as postharvest treatments on the quality of Washington Navel orange fruits during marketing.

Isolation and identification: *Penicillium digitatum* (green mould) and *P. italicum* (blue mould) were isolated from naturally infected Washington Navel orange fruits after storage of several weeks. These isolates were the most aggressive one in our collection and produced the largest lesions on inoculated fruits. These fungi were purified and maintained on Potato Dextrose Agar (PDA) and stored at 4°C, with periodic transfers through citrus fruits to maintain its aggressiveness. Fruits were ready for examination under a stereoscopic binocular microscope (6-50 X) for the presence of fungi and to study their habit characters. When necessary the compound microscope was used for confirming the identification after having examined the morphology of conidia and conidiophores (Singh *et al*., 1991).

Effect of jojoba oil and/or boric acid on linear growth and dry weight of fungi isolated from Washington Navel orange fruits:

- **Linear growth:** Jojoba oil and boric acid were tested in vitro on the linear growth of the pathogenic fungi. Different concentrations were added to 10 mL of sterilized PDA before solidification and then poured in sterile Petri-dishes. After solidification, the plates were inoculated with fungal disc (5 mm) in the center of the plate and incubated at 27±1°C. Three plates for each particular treatment for each fungus were used as replicates; three plates were prepared to serve as control for each fungus. Linear growth was observed daily and diameter of fungal colonies were recorded when plates of any treatment were filled with the fungal growth
- **Dry weight:** One hundred milliliter of liquid PD medium in 250 mL Erlenmeyer flasks were amended with different concentrations of the tested compounds after autoclaving. Each flask was inoculated using two discs of 0.6 mm in diameter of fungal culture, then incubated at 20°C±2 for 7 days. Control flasks contain no concentrations of these compounds. Three replicates were used for each concentration. At the end of incubation period, the mycelium was filtered off and washed several times with distilled water, then dried in an oven at 80°C for 48 h till constant weight (El-Morsy, 1993)

***In vitro* experiments:** Orange fruits were picked from12 year old Washington Navel orange trees budded on Sour orange (*Citrus aurantium*) rootstock grown in a private orchard at Aga city, Dakahlia, Governorate. At both seasons, fruits were harvested at the first week of January which is the optimum maturity stage. Selected fruits were directly transported to the laboratory of post-harvest at Hort. Res. Inst. Mansoura, Egypt. Defective fruits were almost equal in size and apparently insect and pathogen injury free. All fruits were washed with tap water to remove the dust and foreign materials, then air-dried and a quick sorting was done to research fruit for any defects. At the beginning of the experiment, samples of 15 fruits were taken to determine the initial fruits properties and then received the following treatments:

- Control (dipping fruits in tap water)
- Dipping fruits in boric acid (1.0)
- Dipping fruits in jojoba oil (0.1%)
- Dipping fruits in boric acid (1.0%)+jojoba oil (0.1%)

The fruits were left to dry and then packed in one layer inside ventilated carton boxes each consists of 15 fruits. Nine boxes served for each treatment. The total number of boxes were 36 for all treatments and then held at 18°C±1 with 75-80% relative humidity.

The fruits were periodically examined at 15 days intervals until the end of the marketing period (45 day), to determine the following parameters:

- **Disease infection:** It was determined according to the following equation:

$$\text{Disease infection (\%)} = \frac{\text{No. of nutural infected fruits}}{\text{No. of total fruits}} \times 100$$

- **Quality of washington Navel orange fruits:**

- **Loss in fruit weight:** It was determined according to the following equation:

$$\text{Loss in fruit weight (\%)} = \frac{\text{Intial weight} - \text{weight at sampling date}}{\text{Initial fruit weight}} \times 100$$

- **Decay:** It was determined according to the following equation:

$$\text{Decay (\%)} = \frac{\text{Weight of decayed fruits}}{\text{Initial fruit weight}} \times 100$$

- **Total loss in fruit:** It was determined according to the following equation:

Total loss in fruit (%) = Loss weight%+decayed fruits weight%

- **Peel thickness (mm):** Rind thickness of each fruit was measured by digital verneir caliper (Nawaz *et al.*, 2008)

- **Juice percentage:** It was obtained from the following equestion:

$$\text{Juice(\%)} = \frac{\text{Volume of juice (mL)}}{\text{Weight of the whole fruits (g)}} \times 100$$

- **Soluble solids content (SSC%):** Soluble solids content in fruit juice was measured using a Carl-Zeiss hand refractometer according to AOAC (2005)

- **Titratable acidity (TA%):** It was determined in10 mL of fruit juice by titrating with 0.1 N sodium hydroxide in the presence of phenolphthalein as indicator and the results were expressed as a percentage of citric acid according to AOAC (2005)
- **Soluble solids content (SSC)/acid ratio%:** This ratio was calculated from the results recorded for fruit juice SSC and titratable acidity
- **Ascorbic acid (mg 100^{-1} g fresh weight):** Ascorbic acid (vitamin C) was measured by the oxidation of ascorbic acid with 2, 6-dichlorophenol endophenol dye and the results were expressed as mg 100^{-1} g fresh weight according to Ranganna (1979)
- **Ascorbic acid oxidase (AAO) unit/mg protein/min:** The reaction mixture consist of 0.1 mL enzyme extract and 2.9 mL ascorbic acid-phosphate buffer (pH 5.6) prepared as 8.8 mg ascorbic acid dissolved in 300 mL phosphate buffer. The oxidation of ascorbic acid was measured by changes in optical density at 265 nm in 30 sec. intervals for 5 min. The unit of AAO activity was defined as the amount of enzyme which decompose 1 mmol ascorbic acid per minute at 25°C. Protein content of the extracts was determined according to Bradford (1976) using bovine albumin serum as a standard

Statistical analysis: Data of both seasons were analyzed using analysis of variance (ANOVA) technique. Differences among treatment means were statistically compared using the least significant differences test (LSD) at $p = 0.05$ using the CoStat v6.4 program.

RESULTS AND DISCUSSION

The propose of this work was to estimate the effect of postharvest dipping in boric acid and/or jojoba oil alone on fruits quality and decreasing decay of Washington Navel orange during shelf life under ambient conditions at 18°C±1 with 75-80% relative humidity.

Linear growth and dry weight of fungi isolated from washington Navel orange: Data in Table 1 show the effect of dipping with jojoba oil and/or boric acid on linear growth and dry weight of *P. digitatum* and *P. itelicum* isolated from Washington Navel orange fruits. It was also noticed that the reduction in linear growth and dry weight were correlated to the increase in compounds concentrations. Boric acid (1.0%)+jojoba oil (0.1%) treatment were complete inhibition of the linear growth and dry weight of *P. digitatum* and *P. itelicum*. This result is in agreement with the finding of Latifa *et al.* (2011) on citrus who reported complete inhibition of mycelia growth of *P. itelicum* which was generally associated with complete inhibition of sporulation by organic acids and salts.

Data in Table 2 show the effect of dipping with jojoba oil and/or boric acid on disease infection of Washington Navel orange fruits stored for 45 days at room temperature. In both seasons, prolonging the marketing stage resulted in decreased in disease infection with the increase in compounds concentrations. Boric acid (1.0%)+jojoba oil (0.1%) treatment gave the maximum reduction in disease infection caused by *P. digitatum* and *P. itelicum* (0.0%). This result is in agreement with the finding (Troncoso-Rojas and Tiznado-Hernandez, 2007) on fruits and vegetables by chemical alternatives to conventional fungicides for postharvest disease control should be natural or synthetic compounds with known and minimal toxicological effects on mammals and the environment. The origin of these alternatives includes classifications such as food additives and substances listed as GRAS (Generally Regarded as Safe) by the United States Food and Drug Administration, natural compounds obtained from plants, animals or microorganisms

Table 1: Effect of jojoba oil and boric acid on linear growth (cm) and dry weight (g) of fungi isolated from Washington Navel orange fruits

	P. digitatum		*P. itelicum*	
Treatments	Linear growth (cm)	Dry weight (g)	Linear growth (cm)	Dry weight (g)
Control (water)	9.000	1.350	9.000	1.220
Boric acid (0.5%)	6.300	0.945	6.800	0.983
Boric acid (1.0%)	3.200	0.480	4.100	0.615
Boric acid (1.5%)	0.000	0.000	1.300	0.195
Jojoba oil (0.05%)	5.200	0.780	6.100	0.915
Jojoba oil (0.1%)	2.230	0.345	2.130	0.330
Jojoba oil (0.15%)	0.700	0.105	1.100	0.165
Boric acid (1.0%)+Jojoba oil (0.1%)	0.000	0.000	0.000	0.000
LSD at 0.05	1.370	0.081	0.977	0.062

Table 2: Effect of jojoba oil and/or boric acid as postharvest treatments on disease infection% of Washington Navel orange fruits stored for 45 days at room temperature during 2011 and 2012 seasons

	Disease infection (%)							
	P. digitatum				*P. itelicum*			
Treatments	0	15	30	45	0	15	30	45
Season 2011								
Control (water)	0.000	6.30	22.40	66.800	0.00	3.20	17.80	34.60
Boric acid (1.0%)	0.000	3.40	09.80	13.400	0.00	1.40	4.70	07.90
Jojoba oil (0.1%)	0.000	4.20	13.60	21.900	0.00	2.10	6.40	11.10
Boric acid (1.0%)+Jojoba oil (0.1%)	0.000	0.00	0.00	00.000	0.00	0.00	0.00	00.00
LSD at 5%								
Treatments	0.749			00.749				
Time	0.365			00.365				
Treatment time^{-1}	0.730			00.730				
Season 2012								
Control (water)	0.000	5.52	19.63	58.520	0.00	2.68	14.93	29.03
Boric acid (1.0%)	0.000	2.98	08.58	11.740	0.00	1.17	3.94	06.63
Jojoba oil (0.1%)	0.000	3.68	11.91	19.180	0.00	1.76	5.37	09.31
Boric acid (1.0%)+Jojoba oil (0.1%)	0.000	0.00	00.00	00.000	0.00	0.00	0.00	00.00
LSD at 5%								
Treatment	0.749			0.749				
Time	0.365			0.365				
Treatment time^{-1}	0.730			0.730				

including some volatiles and essential oils, phenolic compounds, plant extracts, peptides, alkaloids, lectins, antibiotics, propolis, latex or chitosan and other chemicals such as calcium polysulfide or ammonium molybdate.

Effect of jojoba oil and/or boric acid on orange fruits

Loss in fruit weight percentage: Citrus fruits lose water at low relative humidifies after harvest are prone to stem-end rind breakdown, a physiological injury that can predispose fruit to decay. Table 3 shows that all dipping treatments with jojoba oil and/or boric acid significantly reduced fruit weight loss than the control during both seasons under the study.

Table 3: Effect of jojoba oil and/or boric acid as postharvest treatments on weight loss, decay and total loss of Washington Navel orange fruits stored for 45 days at room temperature during 2011 and 2012 seasons

	Storage period in days											
	Weight loss (%)				Decay (%)				Total loss (%)			
Treatments	0	15	30	45	0	15	30	45	0	15	30	45
Season 2011												
Control (water)	0.000	11.60	17.53	23.36	0.000	11.50	18.30	25.40	0.000	23.10	35.83	48.76
Boric acid (1.0%)	0.000	9.66	13.33	17.93	0.000	09.26	15.30	18.66	0.000	18.92	28.63	36.59
Jojoba oil (0.1%)	0.000	7.63	11.63	17.10	0.000	10.93	16.33	20.50	0.000	18.56	27.96	37.60
Boric acid (1.0%)+Jojoba oil (0.1%)	0.000	4.56	07.46	13.53	0.000	00.00	00.00	00.00	0.000	04.56	07.46	13.53
Mean	0.000	8.36	12.49	17.98	0.000	07.92	12.48	16.14	0.000	16.29	24.97	34.12
LSD at 5%												
Treatments	0.710				0.244				0.878			
Time	0.610				0.499				0.959			
Treatment time^{-1}	1.221				0.998				1.918			
Season 2012												
Control (water)	0.000	7.30	13.56	21.16	0.000	11.23	18.40	24.56	0.000	18.53	31.96	45.72
Boric acid (1.0%)	0.000	5.66	9.46	14.53	0.000	08.36	12.96	17.46	0.000	14.02	22.42	31.99
Jojoba oil (0.1%)	0.000	5.00	8.96	14.13	0.000	09.26	16.03	19.43	0.000	14.26	24.99	33.56
Boric acid (1.0%)+Jojoba oil (0.1%)	0.000	3.30	6.83	11.13	0.000	00.00	00.00	15.96	0.000	03.30	06.83	27.09
Mean	0.000	5.31	9.70	15.24	0.000	07.21	11.85	19.35	0.000	12.53	21.55	34.60
LSD at 5%												
Treatment	0.556				0.580				0.970			
Time	0.489				0.477				0.586			
Treatment time^{-1}	0.979				0.954				1.173			

The prolongation of the marketing stage resulted in increased fruit weight loss. However, control fruits lost 23.36 and 21.16% of their weight in the two seasons, respectively. Fruits estimated to boric acid treatment caused 17.93% in the first season and 14.53% in the second season weight loss, whereas jojoba oil treatment caused 17.10% weight loss in the first season and 14.13 in the second season. The most effective treatment in both seasons were that of boric acid (1.0%)+jojoba oil (0.1%) which recorded fewer weight losses values13.53 and 11.13, respectively, than the other treatments used or the control.

The Application of jojoba-based waxes significantly reduced internal O_2 levels and increased internal CO_2 (Erkan *et al.*, 2005), since Abd El-Moniem *et al.* (2008) found that jojoba treatment reduced weight loss percentage of mango fruits comparing with the control. Additionally, Abd-Allah *et al.* (2012) found that coating persimmon fruits with jojoba oil helped to delay ripening and reduced weight loss and decay percentage.

Decay percentage: Concerning the decay percentage of orange fruit, developed during marketing stage, Table 3 reveals that control fruits became deplorable after 45 days which maintained 25.40 and 24.56% decayed fruits in both seasons, respectively.

Boric acid (1.0%)+jojoba oil (0.1%) did not show any decayed fruit during 45 days in the first season and 30 days in the second season which causes only15.96% decayed fruits after 45 days through shelf life.

Whereas, fruits dipping with jojoba oil alone recorded higher decay percentage 20.50 and 19.43% at two seasons than those dipping with boric acid alone (18.66 and 17.46%, respectively).

Decay was mentioned as one of the limiting factors for postharvest life of citrus fruit because of removing the natural wax of citrus peel through the handling in packinghouses (Huating, 2004).

Boron deficiency is known to alter cell wall structure, membrane integrity, enzyme activity and a wide range of plant metabolites (Goldbach, 1997). Also, boron has been shown to be essential to the structure and function of plant cell walls and membranes (O'Neill *et al.*, 2004).

Wojcik *et al.* (1999) showed that boric acid application to apple fruit play an important role in reduced the infection with *Botrytis cinerea* and decreased fruit bitter pit, internal breakdown and *Gloeosporium*-rot. This related to the disruption effect of boron on cell membrane of the fungal pathogen that resulted in the breakdown of the cell membrane and loss of cytoplasmic materials from the hyphae.

Rolshausen and Gubler (2005) demonstrated that boron could be used for the control of disease in grapevine caused by the fungus *Eutypa lata*. In addition, boron inhibited spore germination and mycelial growth of *B. cinerea*, indicating that the effect of boron against gray mold on table grapes may be directly related to its antifungal activity and has been used extensively in agriculture for control of fungi, bacteria and many insects. Treatment of grapes with boron offers an effective, economical and environmentally safe management strategy to control *B. cinerea*, moreover, boron is an essential plant micronutrient (Qin *et al.*, 2010).

Total loss in fruit percentage: The total loss in weight which including both loss in fruit weight and decayed fruits, are presented in Table 3. It is clear that the total loss in fruit was significantly increased during marketing as storage period prolonged. Moreover, all the applied treatments reduced the percent of total loss in fruit significantly than the control,yet the percent were 48.76% and 45.72% after 45 days through shelf life at room temperature in both seasons, respectively.

Moreover, boric acid (1.0%)+jojoba oil (0.1%) was more effective in reducing the percent of total loss in fruits compared with single application of boric acid or jojoba oil. The percent of total loss due to this treatment were about 13.53 and 27.09% after 45 days during marketing, respectively in both seasons.

In this respect, dipping fruits by boric acid was more effective in reducing the total loss in orange offering about 36.59 and 31.99% compared with jojoba oil presenting about 37.60 and 33.56% under 45 days of shelf life in both seasons equally.

There are two major problems limit the long-term storage capability of citrus fruits; the first is pathological breakdown that leading to decay; the second is physiological breakdown, resulting in the appearance of the various rind disorders (Porat *et al.*, 2004). Abd El-Moniem *et al.* (2008) studied the effect of different coating materials and concluded that coating Washington Navel orange fruits with jojoba oil and orange oil were the best in reducing decay and wet loss with increasing fruits storage life. Hoa *et al.* (2002) treated mango fruits with different coating treatments and found that, all coating treatments reduced the respiratory rate and loss of firmness; also the changes in the acid content were delayed in all coated mangoes.

Ahmed *et al.* (2007) concluded that, the first utilization of trans jojoba oil (TJO) as Valencia orange fruit coating is promising wax than the other investigated coating materials. It can be predicted that TJO coating's resistance to gas exchange is strongly influenced its ability either by blocking pores on the surface of the fruit or, acting as barriers not only to gases migration to restrict respiration, but also to water vapor transfer reducing transpiration and weight loss. So TJO wax can be used successfully without any additives as coating product from natural source. It is substitute or alternative to commercial wax used in handling citrus fruit for export, this facilitate good quality up to 8 weeks which was enough period for sea or land shipment for exported citrus fruit.

The mechanisms by which boron decreased gray mold decay of table grapes may be directly related to the disruption effect of boron on cell membrane of the fungal pathogen that resulted in the breakdown of the cell membrane and loss of cytoplasmic materials from the hyphae (Qin *et al*., 2010).

Soluble solids content (SSC): It is clear from Table 4 that the percent of SSC in fruit juice gradually increased as the storage period advanced during shelf life. The increase in soluble solids content with prolongation of storage period may probably be due to increased hydrolysis of polysaccharides and concentration of juice due to dehydration. The data also disclose that, boric acid at 1.0%+jojoba oil at 0.1% gave a somewhat increment in SSC% in fruit juice (12.26 and 13.83%) than all treatments used or the control during shelf life through both seasons. Since, all treatments used and the control produced fruits with higher significant percent of SSC in fruit juice than those treated with boric acid at 1.0% during the two seasons under the study. In this respect, boric acid at 1.0% provided the lowest percent of SSC which were 11.83 and 12.66% after 45 days through shelf life at room temperature in both seasons, respectively.

Table 4: Effect of jojoba oil and boric acid as postharvest treatments on SSC, titratable acidity and SSC/acid ratio of Washington Navel orange fruits stored for 45 days at room temperature during 2011 and 2012 seasons

	Storage period in days											
	SSC (%)				Acidity (%)				SSC/acid ratio (%)			
Treatments	0	15	30	45	0	15	30	45	0	15	30	45
Season 2011												
Control (water)	10.800	10.16	11.43	12.06	0.605	0.586	0.577	0.532	17.850	17.33	19.80	22.66
Boric acid (1.0%)	10.800	10.86	11.13	11.83	0.605	0.430	0.366	0.390	17.850	25.25	30.40	30.33
Jojoba oil (0.1%)	10.800	10.96	11.56	12.00	0.605	0.463	0.451	0.383	17.850	23.67	25.63	31.33
Boric acid (1.0%)+Jojoba oil (0.1%)	10.800	11.10	11.63	12.26	0.605	0.451	0.394	0.372	17.850	24.61	29.51	32.95
Mean	10.800	10.77	11.44	12.04	0.605	0.482	0.447	0.419	17.850	22.71	26.33	29.31
LSD at 5%												
Treatments	0.226				0.006				0.973			
Time	0.145				0.008				0.546			
Treatment/time	0.290				0.017				1.092			
Season 2012												
Control (water)	11.060	11.23	11.63	13.66	0.664	0.589	0.504	0.578	16.650	19.06	23.05	23.63
Boric acid (1.0%)	11.060	11.40	11.96	12.66	0.664	0.543	0.471	0.412	16.650	20.99	25.39	30.72
Jojoba oil (0.1%)	11.060	11.53	12.13	13.20	0.664	0.554	0.490	0.443	16.650	20.81	24.75	29.79
Boric acid (1.0%)+Jojoba oil (0.1%)	11.060	12.13	12.66	13.83	0.664	0.536	0.476	0.431	16.650	22.63	26.59	32.08
Mean	11.060	11.57	12.10	13.34	0.664	0.555	0.485	0.466	16.650	20.87	24.90	29.05
LSD at 5%												
Treatment	0.151				0.010				0.804			
Time	0.143				0.007				0.481			
Treatment time^{-1}	0.286				0.015				0.963			

Abd El-Motty *et al.* (2007) demonstrated that, preharvest spraying with boric acid treatment at 0.25% after 50 days of storage at 0°C significantly increased T.S.S.% and total sugars% of "Canino" apricot fruit than all treatments used. The obtained results are in agreement with those of Hassan *et al.* (2005) who reported that spraying boric acid increased percentage of total soluble solids in "Canino" apricot.

Asgharzade *et al.* (2012) showed that spraying boron as a pre-harvest treatment had significant effect on texture of apple fruits and increased brix index about 9.18% as compare to control treatment.

Abd-Allah *et al.* (2012) showed that that coating persimmon fruits with jojoba oil helped to delay ripening preserve fruit quality. Also, total sugars were increased gradually with the increase of storage period. However, it seems that sugar content was increased with decreasing jojoba concentration. In this respect, it seems that jojoba oil is benefit natural product to conserve persimmon fruits during cold storage.

Titratable acidity (TA): A gradual decrease in titratable acidity was found in all treatments used from harvest until 45 days through shelf life at room temperature in both seasons. Data from Table 4 demonstrate that all treatments used reduced the percent of total acidity in fruit juice than the control during both seasons. Control fruits retained higher significant percent of TA than all treatments used attaining, 0.53 and 0.57% in both seasons, respectively. Commonly, minimum percent of TA was found in fruit treated with boric acid at 1.0%+jojoba oil at 0.1 attained 0.372% in the first season while, boric acid alone gave the lowest percent (0.412%) in the second season, but the variation was unpronounced.

The decrease in acidity with the storage period might be due to utilization of organic acids in the respiration process. A gradual decrease in acidity has also been reported by Jawandha *et al.* (2012). Moreover, El Bulk *et al.* (1997) concluded that, fruit will reach high levels of sugar, ascorbic acid, soluble solids and their lowest level of acidity as they ripened.

SSC/acid ratio in fruit juice: Considering to SSC/acid ratio, data in Table 4 reveal that the values of SSC/acid ratio were progressively increased by the advance in storage period from harvest till 45 days during shelf life at room temperature. The increment in SSC/acid ratio during the storage period mainly due to the augmentation of SSC content with the reduction in total acidity in fruit juice during the storage period.

With regard to the effect of these treatments on SSC/acid ratio, the data reveal that, boric acid at 1.0%+jojoba oil at 0.1% produced a higher pronounced values of SSC/acid ratio compare to all treatments used (32.95 and 32.08) during both seasons, respectively. Whereas, control fruits reduced the content of SSC/acid ratio pronouncedly through both seasons, since it presented 22.66 and 23.63%, compared with boric acid or jojoba oil alone.

As SSC/acid ratio is a flavoring factor, so these results depicted that with increase in the ratio there was a decrease in the acidity so with low SSC/acid ratio, quality of fruit is poor and taste of fruit becomes watery and insipid. In addition, the ratio is used to determine the fruit maturity standards, so where the ratio is high, fruit will mature earlier. Zekri (2000) reported that the higher the brix: acid ratio, the earlier is the fruit maturity. Hansch and Mendel (2009) mentioned that boron has a main role in many processes specially transport of sugars and carbohydrate metabolism.

Abd-Allah *et al.* (2012) established that coating persimmon fruits with jojoba oil helped to preserve fruit quality and increased both flesh firmness and acid content.

Peel thickness: The thickness of peel is considered to be a character of importance in many fruits. It was noticed that, peel thickness of Washington Navel orange decreased with increasing storage period as shown in Table 5. The peel thickness was significantly higher with boric acid at 1.0% combined with jojoba oil at 0.1% than other treatments. Appeared peel thickness of this treatment was 3.10 and 3.86 mm after 45 days through shelf life at room temperature in both seasons, respectively. Slight differences were noticed in the same period with dipping fruits by boric acid alone in the first season recording 2.86 mm and by jojoba oil in the second season sorting 3.33 mm. Meanwhile the decrease in peel thickness was significantly with control fruits in the second season that realized 2.96 mm after 45 days during shelf life at room temperature.

Some physiological, nutritional and functional properties of the fruits, like the respiratory intensity, the sugar content and the antioxidant capacity, play an indirect role in the enzymatic peeling because they affect the possibilities of storage and the quality of the finished product (Pretel *et al*., 2005). From the molecular point of view, pectin, cellulose and hemicelluloses are responsible for the adherence of the skin to the fruit. Therefore, both pectinases and cellulases are needed for the enzymatic peeling. The cellulases are probably needed for the release of the pectinsin the albedo and the pectinases contribute to the hydrolysis of the polysaccharides of the cell wall (Ismail *et al*., 2005). However, the adherence of the peel to the fruit and its thickness are different according to the species or the citrus varieties and the design of the cuts, the vacuum conditions, temperature and pH also affect the peeling (Pretel *et al*., 2007).

Table 5: Effect of jojoba oil and/or boric acid as postharvest treatments on peel thickness, juice volume, ascorbic acid and ascorbic acid oxidase (AAO)of Washington Navel orange fruits stored for 45 days at room temperature during 2011 and 2012 seasons

	Storage period in days															
	Peel thickness				Juice volume				Ascorbic acid				AAO			
Treatments	0	15	30	45	0	15	30	45	0	15	30	45	0	15	30	45
Season 2011																
Control (water)	3.630	2.90	2.73	2.76	83.40	76.30	74.20	73.26	36.360	34.23	30.70	29.86	0.470	0.50	0.56	0.63
Boric acid (1.0%)	3.630	3.10	2.93	2.86	83.40	78.86	77.86	76.73	36.360	34.10	33.76	32.10	0.470	0.51	0.48	0.58
Jojoba oil (0.1%)	3.630	2.80	2.73	2.66	83.40	79.36	78.13	75.56	36.360	34.50	33.00	32.96	0.470	0.51	0.52	0.56
Boric acid (1.0%)+Jojoba oil (0.1%)	3.630	3.50	3.26	3.10	83.40	83.16	81.30	80.90	36.360	35.00	34.80	34.16	0.470	0.53	0.47	0.50
Mean	3.630	3.07	2.91	2.85	83.40	79.42	77.87	76.61	36.360	34.45	33.06	32.27	0.470	0.51	0.51	0.57
LSD at 5%																
Treatment	0.144				01.67				0.280				0.011			
Time	0.093				01.72				0.124				0.011			
Treatment time^{-1}	0.186				03.44				0.248				0.022			
Season 2012																
Control (water)	4.000	3.33	3.06	2.96	90.96	86.73	84.30	81.86	35.100	32.03	30.06	29.33	0.400	0.47	0.54	0.58
Boric acid (1.0%)	4.000	3.66	3.33	3.06	90.96	83.96	86.43	85.06	35.100	32.16	31.13	29.83	0.400	0.47	0.51	0.55
Jojoba oil (0.1%)	4.000	3.76	3.56	3.33	90.96	87.86	88.50	88.20	35.100	33.13	31.70	30.16	0.400	0.44	0.48	0.48
Boric acid (1.0%)+Jojoba oil (0.1%)	4.000	3.93	3.80	3.86	90.96	87.13	89.86	88.83	35.100	34.43	32.36	31.36	0.400	0.41	0.46	0.46
Mean	4.000	3.67	3.44	3.30	90.96	86.42	87.27	85.99	35.100	32.94	31.31	30.17	0.400	0.45	0.50	0.52
LSD at 5%																
Treatment	0.154				1.69				0.199				0.008			
Time	0.146				1.66				0.165				0.010			
Treatment time^{-1}	0.293				3.33				0.330				0.021			

Juice volume: In many citrus, the juice content of fruits is estimated to be higher with thinner the peels. The amount of juice present in a fruit is considered to be one of the most important qualities in juicy fruits like citrus wherever, only the juice comprises the human consumable part in the fruit.

Data in Table 5 indicated that the percent of juice volume gradually decreased from harvest till 45 days as a storage period advanced during shelf life. Boric acid 1.0%+jojoba oil 0.1% was more effective in reducing the losses percent of juice volume of orange fruits significantly compared with boric acid or jojoba oil each alone. The percent of juice volume due to this treatment was about 80.90 and 88.83% after 45 days during marketing, respectively in both seasons.

The maturity of fruit is assessed from the color, juice content, TSS and acidity of the juice. Since, juice yield of the oranges increased during the first two months of the storage then decreased during the rest of storage period (Erkan *et al.*, 2005).

Ascorbic acid: Data presented in Table 5 indicated that, vitamin C contents of orange decreased gradually during shelf life. This finding could be attributed to the conversion of ascorbic acid to dehydro ascorbic acid and decreasing the active form of ascorbic (Hacisevki, 2009). The reduction in ascorbic acid at control fruits ranged in the first season from 36.36-29.86 mg 100 g^{-1} fresh weight (about 17.90%) and realized in the second one from 35.10 to 29.33 mg 100 g^{-1} fresh weight (about 16.43% losses). This finding is correlated to the previously mentioned about SSC/acid ratio, where these fruits recorded less fruit quality characters.

On contrary, the high pronounced ascorbic acid values were found with boric acid (1.0%)+jojoba oil (0.1%), since the reduction in ascorbic acid content in this treatment ranged from 36.36-34.16 mg (the percent of decline reached 6.04%) and from 35.10 to 31.36 mg (the percent of decline reached 10.62%), after 45days of shelf life at room temperature in both seasons, respectively. Ascorbic acid is an important nutrient quality parameter and is very sensitive to degradation due to its oxidation compared too there nutrients during food processing and storage (Veltman *et al.*, 2000). Ascorbic acid is also involved in the cell cycle (Kerk and Feldman, 1995) and in other important enzyme reactions in plant issues (i.e., ethylene biosynthesis).

Ascorbic acid oxidase (AAO): Ascorbic acid oxidase (AAO; EC 1.10.3.3.) is a Cu-containing enzyme that catalyzes the oxidation of ascorbate to 2-dehydroascorbate with the concomitant reduction of molecular oxygen to water (Ohkawa *et al.*, 1989). Also, AAO an enzyme in plant tissues that oxidizes ascorbic acid to dehydro-ascorbic acid; it is only released when the plant wilts or is cut.

From data presented in Table 5, AAO activity in fruit juice of orange gradually increased during shelf life in both seasons. Moreover, all the applied treatments reduced the activity of AAO in fruit significantly than the control stored for 45 days at room temperature. Since, the percent in control fruits were 0.63 and 0.58% after 45 days through shelf life at room temperature in both seasons, respectively. Furthermore, boric acid 1.0%+jojoba oil 0.1% was more effective in reducing the activity of AAO in orange fruits compared with boric acid or jojoba oil each alone. The percent of AAO due to this treatment was about 0.50 and 0.46% after 45 days during marketing, respectively, in both seasons.

The storage period had a more significant effect on the content of ascorbic acid than the temperatures did. It has previously been reported that a loss of ascorbic acid in citrus fruit is not caused by storage temperature (Rapisarda *et al.*, 2008) and that there was no loss of ascorbic acid during storage of oranges at low temperature. The oxidation of ascorbic acid by mature fruit would probably be due to one or more of the following agents, typical AAO such as that found in green fruit, copper ions, polyphenoloxidase and/or an atypical ascorbic acid oxidase.

Ascorbic acid oxidation leads to the destruction of vitamin C and the loss of nutrition in foods. This browning is the spontaneous thermal decomposition of ascorbic acid under both aerobic and anaerobic conditions. It was reported that over 80% of the browning of dried apple during storage packed under vacuum resulted from oxidative non-enzymatic reaction (Bolin and Steele, 1987).

In the presence of the enzyme, vitamin C is oxidized in the attendance of air by copper to give hydrogen peroxide which destroys ascorbic acid. Ascorbic acid oxidase is a copper containing enzyme which catalyzes the oxidation of ascorbic acid to dehydro ascorbic acid and water. However, during extraction of fruit juice, ascorbic acid oxidase activity increases (Hacisevki, 2009).

Blood oranges present suitable characteristics for preparation as ready-to-eat products. During shelf-life, such produce could be susceptible to quality degradation due to the action of some enzymes, among which polyphenol oxidase (PPO) and ascorbate oxidase (AAO), considered as two markers of oxidation and reduction of anthocyanins and ascorbic acid. PPO activity was very low, probably due to the low pH of oranges; furthermore, it was noticed that the decrease of phenols and anthocyanins content did not have a statistically significant relation with PPO activity course during storage. Otherwise, AAO activity was very high and correlated to the decrease of vitamin C content. Nevertheless, such decrease did not exceed 20-30% of the initial ascorbic acid content (Ingallinera *et al.*, 2005).

CONCLUSION

It could be concluded that, the combination treatment of boric acid (1.0%) plus jojoba oil (0.1%) was the most effective treatment in decreasing weight losses, fruit decay, total loses in fruit, titratable acidity and ascorbic acid oxidase, as well as linear growth, dry weight and disease infection percentage of the tested pathogenic fungi. However, increasing soluble solids, SSC/acid ratio, peel thickness, ascorbic acid content and juice percent is reported by such treatment.

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