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Sodium Bicarbonate Application as an Alternative Control of Postharvest Decay of Blood Orange Fruits

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Abstract: Sodium bicarbonate (SB) as an effective alternative to the use of chemicals to control postharvest decay of blood orange fruits was studied alone or in combination with curing exposure against decay incidence of two strains (A and B) of blood orange fruits during cold storage. Full colored fruits were immersed in 3 % SB at 20°C for 2 min, after that exposed to curing temperatures at 30 or 35°C and 90-95 % RH for 48 and 72 h. All treated and untreated orange fruits were stored after previous applications at 5°C and 90 % relative humidity (RH) for 42 days and additional week at 20°C as a simulated marketing period (shelf-life). Fruit quality characteristics i.e. weight loss and decay percentages, soluble solids (SSC), total acidity (TA), vitamin C and anthocyanin contents were evaluated. Treated and control fruits withstand free from pathogenic rots or microbial fruit deterioration up to 42 days of cold storage period. Moreover, Curing temperature exposure at 35°C either for 48 or 72 h showed higher response of controlling orange fruit deterioration and reducing weight loss percent compared with curing at 30°C. Soluble solids content and total acidity revealed a response varied between insignificant or slight effect values due to SB and curing treatments. Throughout cold storage period, ascorbic acid content was decreased significantly in all treated and control fruits due SB and curing application and storage duration. Moreover, orange fruits of strain A kept higher ascorbic acid content than those of fruits of strain A. On the other side, anthocyanine concentrations showed higher content in fruits of strain B than that of strain B, with more effective response in curing at 35°C either for 48h than 30°C and 72h. Although untreated fruits had the highest physiological decay percent, and fruit quality characteristics, non-cured fruits showed intermediate values in blood orange fruits of both strains. It can be concluded that the response of all treatments examined under storage periods tested was more effective in blood orange fruits of strain B than those of strain A, especially in ascorbic acid and anthocyanine contents.

Keywords: Blood orange, sodium bicarbonate, curing, decay control, alternative materials, cold storage, fruit quality, shelf-life.

INTRODUCTION

The most common and serious diseases that affect citrus fruit are green and blue molds[1,2]. Synthetic fungicides have been the main method of control citrus postharvest diseases including green and blue molds[3]. Currently, both diseases are primarily controlled by application of the fungicides. Alternative methods are needed because the widespread use of these chemicals in commercial packinghouses has led to the proliferation of resistant strains of these pathogens[4]. Furthermore, concerning the public health and environmental issues have increased the needed for alternative[5,6].

Recently, Palou *et al.,*[5] reported a reduction up to 90 % in the incidence of both green and blue molds after treating artificially inoculated fruit with different concentrations of SB. Sodium bicarbonate (SB) is grouped under items generally regards as safe by the United States Food and Drug Administration and has been used as a disinfectant for citrus fruit since 1920 [3]. Also, it is classified, as generally recognized, as safe material by the Food and Drug Administration and also proposed exempt from residue tolerances in all agricultural commodities by the United States Environmental Protection Agency. Moreover, when sodium bicarbonate was applied at room temperature at 2 to 4 %, blue mold reduced by more than 50 %. Moreover, the influence of commercial postharvest practices on control of green mold by sodium carbonate and sodium bicarbonate was published to facilitate their commercial adoption[5,7].

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As early as 1948, control of green mold of oranges was shown to be reduced by holding fruit for several days after harvest at 30°C and 90-100% RH. These conditions subsequently were shown to elicit the biosynthesis of lignin and its phenolic precursor in the outer pericarp (flavido) of the fruit while reducing the growth of *penicillium digitatum*[8,9]. Holding citrus fruit at 32-36°C and 94-98 RH for 2-3 days controls *P. digitatum* during postharvest storage at different temperatures. However, no information is available on the effect of curing such fruits stored at 4°C, while the temperature used for long-term storage by several countries [10].

Recently, blood orange has been popular in Europe and now it has gained the popularity in the US and can be found fresh or in juice[11]. Egyptian export policies are planned to satisfy the needs of international markets demands as fresh products with high quality fruits.

The objective of such work was to evaluate the response of alternative and organic materials as sodium bicarbonate and curing applications to manage postharvest decay of blood orange fruits during cold storage periods and marketable life.

MATERIALS AND METHODS

Fruit: Two strains (A and B) of blood orange fruits (*Citrus sinensis lin.*) were obtained from a private orchard (Dina), Giza Governorate. Fruits were picked from trees grown in sandy loam soil, similar in growth and received common horticulture practices. Mature blood orange fruits, undamaged, free from apparent pathogen infection and uniformed in shape, weight and color were harvested at the late of January of 2005 and 2006 in the full color stage and transported to the laboratory of Agriculture Development Systems (ADS) project in the Faculty of Agriculture, Cairo University. The initial quality measurements were determined.

Curing and Sodium Bicarbonate Treatments: The selected fruits from each strain washed with tap water, air dried, placed into plastic baskets and immersed for 2 min in 20 liter tanks containing 3 % (w/v) sodium bicarbonate solution (pH 8.3 to 8.6; Sigma-Aldrich) at room temperature (20°C +1), using stainless steel tanks, each one individually fitted with an electrical heater, a temperature sensor, and a mechanical agitation system. The pH of sodium bicarbonate solutions rises rapidly at high temperature; therefore, only curing at 20°C was tested. Untreated orange fruits (control) immersed in tap water for the same period.

After treatment, the fruits were rinsed with 10 ml of deionized water per fruit and each treatment was applied to three replicates of 5 fruit for each and the experiment was repeated twice. Treated fruit with sodium bicarbonate were placed into plastic cavity trays and cured at two temperatures (30 and 35°C) and 90-95 % relative humidity for 48 or 72 h. After that, all treated and untreated fruits stored at 5°C put under + put - and 90 % RH up to 42 days. The initial fruit quality characteristics of both blood orange strains after treatments were measured (0 storage day).

At 21 days intervals, fruit samples (20 fruits in each treatment) were removed from cold storage and fruit quality measurements were assessed. Shelf-life as a simulation for marketability was examined for decay percent at 20°C up to 7 days.

Fruit Quality Assessments:

Weight Loss: Orange fruits were periodically weighed and the loss in mass weight was recorded for each replicate. Data were calculated as percentage from the initial weight.

Decay Percentage: Decay was evaluated as skin appearance, shriveling, chilling injury, and pathogenic rots. In every inspection, decayed fruits were discarded and the number of fruits per replicate was used to express decay percentage. Storage was stopped when decay assessment reached 25 % in stored fruits. After each sample, shelf –life as marketability indicator was determined at 20°C for one week.

Soluble Solids Content (SSC): measured using a T/C hand refractometer Instrone (Model 10430 Brix–readings 0 - 30 ranges Bausch & Lomb Co. Calif., USA) according to[12].

Total Acidity (TA): (expressed as citric acid) was determined by titrating 5 – ml juice with 0.1N sodium hydroxide using phenolphthalein as an indicator [12].

Ascorbic Acid Content (VC): measured using 2-6 dichlorophenol indophenols blue dye, method described by[12].

Total Anthocayanin: One gram from the mixture of fruits skin was grounded with 95% ethyl alcohol and HCl. The mixture was then filtered through centered glass funnel (G3) and the extract was transferred to 25 m/volumetric flask and completed to volume with the acidified alcohol. The optical density at 550 mm represents the concentration of total anthocyanin[13].

Experimental Design and Statistical Analysis: The design for this experiment was a Completely Randomized Design (CRD) with three replications. Data were analyzed with the Analysis of Variance

(ANOVA) procedure of MSTAT-C program. When significant differences were detected, treatment means were compared by LSD range test at the 5 % level of probability in the two investigated seasons[14].

RESULTS AND DISCUSSIONS

Weight Loss Percent: Blood orange fruits of strains A and B showed a gradual and significant increase in weight loss percent with directly proportional to the storage period, as shown in (Table 1). Meanwhile, orange fruits of both strains appeared similar significant mass loss, but with lower percent in strain B than that in strain A either after sodium bicarbonate (SB) treatments or throughout cold storage at 5°C.

It can be noticed from data presented in (Table 1), that fruits previously treated with SB at 3 % for 3min and cured at 30°C, had lower significant weight reduction than fruits received the same application and cured at 35°C in the two curing durations for 48 or 72 h during cold storage period for both strains. At the end of successive cold storage period for 42 days, the least significant weight loss percent (5.99 %) was observed in blood orange fruits of strain B treated with 3 % sodium bicarbonate and cured at 30°C for 72 h.

Moreover, the highest loss (11.30 %) in fruits of strain A stored up to 42 days at 5°C after SB application without curing, followed by untreated fruits recorded 10.21 %of weight loss percent. On the other side, blood orange fruits of strain B received SB treatments without curing, had intermediate value (9.10 %) of weight loss percent after cold storage period at 5°C of the two successive seasons of this investigation. In this concern, it can be concluded that utilization of sodium bicarbonate at 3% reduced weight loss percentage of blood orange fruits. While, curing after SB applications showed more effective response.

The present results are confirmed the findings of[10,15], they reported that Valencia orange fruits and Lemons cured at 40 to 55°C and stored at 5°C, showed a significant reduction on weight loss pe

Table 1: Weight loss percentage of strains A and B of blood orange fruits as affected by sodium bicarbonate treatment at 20°C and curing temperatures at 30 or 35°C for 48 and 72 h, after treatments and during storage at 5°C for 42 days.

			Weight loss %					
			Strain A			Strain B		
Sodium bicarbonate treatments	Curing temperatures	Curing duration	Storage at 5 °C for 42 days					
			0	21	42	0	21	42
Untreated			0.00 e	5.23 b	10.21 b	0.00 e	4.61 bc	7.93 b
$NaHCO_3$	30°C	48 h	2.14 c	4.51 cd	7.06 cd	2.01 d	4.18 d	6.11 d
$NaHCO_3$	35°C		2.79 b	4.73 cd	7.03 cd	2.92 b	4.79 b	6.86 c
$NaHCO_3$	30°C	72 h	1.85 d	4.39 d	6.74 d	1.87 d	3.85 e	5.99 d
$NaHCO_3$	35°C		2.76 b	4.82 bc	7.19 bc	2.64 c	4.36 cd	6.17 d
$NaHCO_3$	Without curing		4.01 a	6.40 a	11.30 a	3.45 a	5.20 a	9.10 a
LSD at 0.05			0.20	0.42	0.39	0.20	0.29	0.42

Data are means of three replicates of 5 fruits each (average of two seasons)

Table 2: Physiological decay percent of strain A and B of blood orange fruits as affected by sodium bicarbonate treatment at 20°C and curing temperatures at 30 or 35°C for 48 and 72 h, after storage at 5°C for 42 days and plus 7 days at 20°C as shelf – life.

			Physiological decay %			
			Strain A		Strain B	
bicarbonate treatments	Curing temperatures	Curing duration	Storage at 5°C for 42 days			
			At transfer	Plus 7 d at 20°C	At transfer	Plus 7 d. at 20°C
Untreated			15.67 a	18.03 a	13.75 a	16.65 a
$NaHCO_3$	30°C	48 h	3.52 f	4.16 f	0.00 d	0.00 d
$NaHCO_3$	35°C		4.39 d	5.16 d	0.00 d	0.00 d
$NaHCO_3$	30°C	72 h	3.73 e	4.76 e	0.00 d	0.00 d
$NaHCO_3$	35°C		5.69 b	7.22 b	1.53 c	2.79 c
$NaHCO_3$	Without curing		5.19 c	6.67 c	3.28 b	4.17 b
LSD at a 0.05			0.130	0.010	0.010	1.236

Data are means of three replicates of 5 fruits each (average of two seasons)

rcent. On the other hand, the results obtained by[9], revealed higher weight loss values in cured fruits of mandarin than non-cured fruits. Moreover, Palou *et al.,*[5] found that temperatures of sodium bicarbonate solutions on orange fruits appeared effectiveness more than concentration or immersion period. Furthermore, Henroid, *et al.,*[11] reported that Navel orange fruits stored for 55 days at 5°C and 21 day at 21°C lost 3% and 13%, respectively of their initial weight.

Physiological Decay Percent: Throughout this experiment, there was no pathogenic rots was observed in the peel of blood orange fruits of both strains (A and B) after 42 days of cold storage at 5°C as well as after 7 days at 20°C (shelf-life).

Data presented in (Table 2) cleared that orange fruits of strain B treated with 3 % sodium bicarbonate (SB) and cured either at 30 or 35°C for 48 h, withstand free from any physiological injuries after cold storage for 42 days and also during shelf –life at 20°C. The same trend was noticed in fruits of strain B received SB applications and cured at 30°C for 72 h, neither at transfer from cold storage nor plus one week of marketable life.

On the other hand, blood orange fruits of strain A, showed the least physiological disorders percent (3.52 and 3.73) after storage for 42 days and previously received SB and cured treatments at 30°C for 48 or 72 h, respectively. The same observations were noticed after 7 days at 20°C recorded (4.16 and 4.76%) when compared with uncured fruits which appeared 5.19 and 6.67 % after cold storage at 5°C and plus 7day at 20°C, respectively. Moreover, untreated fruits (control) had the highest percent of decay (15.67 and 13.75%) of strain A and B respectively after storage at 5°C for 42 days. Further increase in physiological deterioration percent was obtained after shelf period for 7 days at 20°C.

In this concern, the results of[10] showed that holding citrus fruit at 32-36°C and 94-98 RH for 2-3 days controls *P. digitatum* during postharvest storage at different temperatures. Also, Palou *et al.,*[5,1] confirmed the previous results of orange and mandarin fruits, when they found that control green and blue molds were reduced by curing treatments. In addition, El-Ghaouth *et al.,*[16,4] reported that biological control is increasingly becoming an effective alternative to the use of chemicals in citrus disease control. Moreover, a reduction of up 90 % in the incidence of both green and blue molds after treating artificially inoculated fruit with different concentrations of sodium bicarbonate [3]. Similarly, sodium bicarbonate and hot water applied for 150s at 45°C for 3 or 4 % reduced decay more than 90% on mandarin, lemons, and orange fruits, respectively[17,5,15]. They added that the influence of commercial postharvest practices on control of green mold by and sodium bicarbonate was published to facilitate their commercial adoption.

Fruit Quality Evaluations:

Soluble Solids Content: There was a slight and significant progressive increase in soluble solids content of blood orange fruits during cold storage period up to 42 days as presented in Tables 3 and 4. It can be noticed that blood orange fruits of both strains (A and B) appeared the same SSC trend due to sodium bicarbonate (SB) treatments and curing temperatures exposure. Meanwhile, orange fruits of strain A had higher soluble solids values compared with those of strain B fruits. Cured fruits at 35°C for 48 h after SB application showed higher SSC percent than those cured at 30°C, while curing for 72 h revealed the opposite trend either in fruits of strain A or those of strain B. In addition, untreated oranges have the highest soluble solids content followed by fruits previously treated with sodium bicarbonate without curing and then stored for 42 days at 5°C.

The present results are in harmony with those reported by[5,15] noticed that soluble solids content of cured mandarin fruits was higher than non-cured fruits. An opposite trend was obtained by [9] which found no significant effect to curing application on mandarin than untreated fruits (control). In addition, Saidani and Marzouk,[18] reported that no adverse effects quality attributes to soluble solids content of blood orange fruit as response to heat applications.

Total Acidity: Concerning the changes of total acid content of the two strains of blood orange fruits due to SB and curing treatments during cold storage periods at 5°C (Tables 3 and 4), there was a slight insignificant reduction in fruits acid content as the storage period progress. However, total acid content was decreased with lower curing temperature at 30°C for 48h. Further reduction of total acid values was obtained in blood orange fruits of strain A cured at 35°C for 72 h. Moreover, orange fruits of strain B treated with SB and curing before cold storage showed an opposite trend in reducing acid content in fruits of strain A cured previously at 30°C for 48h without any significant influence (Table 4). At the end of cold storage period, orange fruits received sodium bicarbonate applications without curing showed the least acid values (0.90 and 1.00%) in fruits of strain A and strain B, respectively. While, control fruits of strain B recorded the highest acid content (1.22%).

These results are in harmony with those reported by[18,7] which noticed that hot water treatments (HWT) as an effective pretreatment to maintain postharvest quality had no adverse effects on titratable acidity in blood orange and Satsuma mandarin fruits after cold

Table 3: Fruit quality characteristics of strain A of blood orange fruits as affected by sodium bicarbonate treatment at 20°C and curing temperatures at 30 or 35°C for 48 and 72 h, after treatments and during storage at 5°C for 42 days.

			Fruit quality characteristics											
			Strain A											
			Soluble solids content			Total acidity %			Vitamin C (mg/100g)			Anthocyanin (mg/100g)		
Sodium Bicarbonate Treatments	Curing temper-atures	Curing Time	Storage in days at 5°C											
			0	21	42	0	21	42	0	21	42	0	21	42
Untreated			10.90	11.42	11.90	1.20	1.15	1.10	48.5	46.83	41.10	0.009	0.048	0.066
$NaHCO_3$	30°C	48 h	10.40	11.17	11.17	1.11	1.10	1.10	43.8	43.8	40.4	0.021	0.019	0.045
$NaHCO_3$	35°C		10.33	11.00	11.70	1.22	1.20	1.20	46.7	46.7	45.5	0.010	0.022	0.045
$NaHCO_3$	30°C	72 h	10.80	11.60	12.00	1.15	1.09	1.20	46.1	44.6	37.6	0.012	0.023	0.048
$NaHCO_3$	35°C		10.43	11.50	11.70	1.04	0.92	1.05	46.7	46.7	41.5	0.009	0.028	0.046
$NaHCO_3$	Without curing		11.00	11.40	11.80	1.00	0.90	0.90	43.0	42.6	39.2	0.007	0.019	0.049
LSD at 0.05	NS		0..33	0.42	0.15	0.20	0.13	2.37	2.40	1.06	0.004	0.006	0.006	

Data are means of three replicates of 5 fruits each (average of two seasons)

Table 4: Fruit quality characteristics of strain B of blood orange fruits as affected by sodium bicarbonate treatment at 20°C and curing temperatures at 30 or 35°C for 48 and 72 h, after treatments and during storage at 5°C for 42 days.

			Fruit quality characteristics											
			Strain B											
			Soluble solids content			Total acidity %			Vitamin C (mg/100g)			Anthocyanin (mg/100g)		
Sodium Bicarbonate Treatments	Curing temper-atures	Curing Time	Storage in days at 5°C											
			0	21	42	0	21	42	0	21	42	0	21	42
Untreated			10.40	10.90	11.20	1.22	1.10	1.22	44.64	40.00	44.14	0.012	0.027	0.080
$NaHCO_3$	30°C	48 hours	10.10	10.60	10.88	1.20	1.10	1.20	43.12	38.40	43.12	0.007	0.038	0.051
$NaHCO_3$	35°C		10.10	10.75	11.00	1.07	1.00	1.07	42.30	36.80	42.30	0.008	0.038	0.070
$NaHCO_3$	30°C	72 hours	10.80	11.00	11.17	1.07	1.02	1.04	44.40	38.10	44.20	0.006	0.029	0.043
$NaHCO_3$	35°C		10.70	10.82	11.10	1.14	1.00	1.11	42.74	38.50	42.74	0.004	0.041	0.061
$NaHCO_3$	Without curing		10.00	10.70	11.00	1.03	0.90	1.00	42.80	38.00	41.80	0.007	0.020 b	0.060
LSD at a 0.05			NS	0.29	0.36	NS	NS	NS	1.34	1.82	1.91	0.003	0.016	0.029

Data are means of three replicates of 5 fruits each (average of two seasons)

storage at 5°C. Moreover, Obagwu, and Korsten,[3] found that sodium bicarbonate and curing temperatures treatments caused significant reduction in total acid content of citrus fruits grown in different regions. In addition, after cold storage period, significant reduction in total acidity was observed in cured treated Clementine fruits[19,9].

Ascorbic Acid Content (Vitamin C): The changes of ascorbic acid content of blood orange fruits of the two strains revealed a progressive and significant decrease through cold storage period at 5°C as influenced by sodium bicarbonate (SB) and curing treatments, including control fruits as shown in (Tables 3 and 4). In general, untreated fruits kept the highest content of vitamin C (48.5 and 44.64 mg /100gm) after SB and curing applications in fruits of strain A and B, respectively. Meanwhile, after 42 days of cold storage at 5°C, control fruits of strain B had higher ascorbic acid content (44.14 mg /100gm) than those of strain A (41.10 mg /100gm).

Curing temperatures at 35°C for 48h was more effective in keeping vitamin C content than curing at 35oC for 72h in blood orange fruits of strain A. However, an insignificant reduction of ascorbic acid content was obtained in fruits of strain B received 3 % SB and cured at 30°C for 48 or 72 h. In addition, blood orange fruits treated previously with SB and cold stored without curing had an intermediate content of ascorbic acid between treated and untreated fruits of both strains.

In this concern, results obtained as curing treatments response confirmed the findings of[11] who noticed that ascorbic acid of mandarin fruits were lower in cured fruit than control and hot water dipped fruits. In addition, vitamin C levels decreased in all stored fruits with slightly lower values in cured treated mandarin fruits than in the control fruits[18,9]. In addition, there are no consistent effects on ascorbic acid content due to curing applications of Valencia oranges and mandarin fruits were recommended by[15,19] during storage and shelf-life periods.

Total Anthocyanin Content: It is clear from Tables (3 and 4) that total anthocyanin content in the pulp of blood orange fruits of both strains, showed gradual and significant increase throughout cold storage period either in untreated fruits or fruits treated with sodium bicarbonate and curing applications. It can be stated that fruits of strain B had higher total anthocyanin concentrations than those of strain A in all tested periods of storage, and among the two successive seasons of such study.

At the end of cold storage duration for 42 days, blood orange fruits of strain A received SB application and cured at 30 and 35oC for 48 or 72 h appeared insignificant and approximately equal content of anthocyanin (0.045 to 0.048 mg /100gm), in comparison with control fruits which recorded higher total anthocyanin content (o.066 mg /100gm). On the other side, fruits of strain B showed significant and higher anthocyanin concentrations (0.070 and 0.061 mg /100gm) in fruits treated with sodium bicarbonate and cured at 35°C for 48 and 72h respectively, than those cured at 30°C for 48 and 72h which recorded (0.051 and 0.043 mg /100gm) of anthocyanin content respectively at the end of cold storage period.

In parallel to the present results, Emanuele, *et al,*[20,18] reported that sodium carbonate treatments decreased peel color and anthocyanin concentrations of blood orange fruits. Meanwhile, the results of hot water application to Satsuma mandarin confirmed that pre-postharvest heat treatments caused significant effective utilization to maintain fruit quality during storage and marketing life [7]. In addition, Erkan *et al.,*[15] noticed opposite trend due to hot water treatments on Valencia orange fruits. Moreover, the intermittent curing treatments reduced color content in mandarin fruits than control and non-cured ones[9].

Conclusions: It can be concluded that, the two strains of blood orange fruits is strongly influenced by sodium bicarbonate applications and curing exposure and stored in a good quality for 42 days. Sodium bicarbonate was substitute or alternative to fungicides or chemical materials used in controlling injuries and fruit deteriorations during storage duration as handling citrus fruit for export. Moreover, blood orange fruits of strain B was more effective response of all treatments examined under storage periods tested than those of strain A, especially in ascorbic acid and anthocyanin contents.

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