International Journal on Food, Agriculture, and Natural Resources
Volume 6, Issue 1, Page 20-25
ISSN: 2722-4066
http://www.fanres.org

Original Paper

Effect Of Pre-Storage Steam Treatment On Shelf-Life of Kings' Orange (Citrus Sinensis CV. Nobilis) Fruits During Ambient Storage

Oluwalonimi G. Faniyi[1], Abiola T. Aborisade[2]*
1) *The Federal University of Technology, School of Life Sciences, Department of Biology, Akure, Nigeria*
*) *Corresponding Author:* ataborisade@futa.edu.ng

Received: 14 November 2024; Revised: 14 November 2024; Accepted: 03 March 2025
DOI: https://doi.org/10.46676/ij-fanres.v6i1.431

***Abstract*— Fresh fruits are susceptible to fungal rots, but postharvest decay control can be applied by physical, chemical, biological, and cultural techniques. Uninoculated 'Kings' orange (Citrus sinensis cv. Nobilis) fruits exposed to steam prior to ambient storage were analyzed for quality. Rot occurrence was between 3.3 and 13.3 % weekly increasing with storage. There was no definite trend especially after the first two weeks though initially higher on the most severely heated fruits. Penicillium digitatum, Lasiodiplodia theobromae and Aspergillus niger were associated with rots. Weekly and cumulative weight losses were highest among fruits that received the mildest heat treatment at 55 °C for 25 minutes. Juice content was higher in steam treated fruits though not statistically significantly. Juice pH was more significantly affected by heating as the more severe heat treatments resulted into less acid in the first two weeks but more, later in storage. Titratable acid content was 0.48 to 0.77. In the fifth week, slightly significant reduction in titratable acid occurred in fruits that were heated at 60 °C for 25 minutes compared with control, but it was more significant in comparison with juice from fruits heated at the lower temperature. There were increases in total soluble solids content with storage but insignificant differences between treatments. These results show that the presently applied steam treatments did not have significant undesirable effect on the fruit juice quality during subsequent ambient storage of fruits.**

***Keywords*— ambient, fruits, quality, rot, steam**

I. INTRODUCTION

Thi Pre-storage heat treatments have effect on quality of fresh fruits afterward, and may therefore affect their acceptability by consumers [13, 14]. The cultivar of orange fruits referred to as 'Kings' in parts of Southwest, Nigeria is desired for the extra sweet taste, juiciness, tartness and cloud, in addition to the rich content of vitamin C, minerals, and citric acid, all suspended in water which makes up greater than 80% of the fresh weight. The fruit is perishable, lasting only a few days after harvest, especially under tropical conditions. The rich nutrient content and consumer appeal of the fruit and its products gives it potentially high economic value although its cultivation and availability in Nigeria is not yet widespread. Extending the life of the fruit in the unprocessed fresh state beyond the harvest season is therefore desirable for all year availability, nutritional and economic benefit.

Different techniques are in use for the preservation of unprocessed perishable commodities [15, 16, 19, 22, 35]. Heat treatments however present the advantage of produce decontamination, eliminating the microorganisms that could otherwise cause deteriorations in form of wilts, rots and anthracnoses which could result into taste defects or total loss of fruit. It also has the advantage of safety as conventional fungicides may leave residues if used as alternative, and become potentially harmful to health if consumed by humans [8, 12].

Steam treatment of whole fruits have the advantage of higher heat penetration power than dry air, achieving produce decontamination in less time [26, 27] with potential greater retention of quality attributes [6, 23]. Reports indicate that pre-storage steam treatment of citruses is not as common as other heat treatment methods which include hot water rinsing and brushing (HWRB), curing, and hot water dips [13, 20, 24, 28] though it could be more advantageous. Heating Cactus pear fruit (Opuntia ficus-indica Mill. cv. Gialla) at 38° C for 24h under saturated humidity simulating steam, reduced rot development and decline in overall fruit appearance [32]. The control of green mould, Penicillium digitatum on orange fruits was also promoted by moderate heating at 30° C for 24h in saturated atmosphere because it enhanced the activities of the biocontrol bacterium, Pseudomonas glathei which retarded spore germination of the fungal pathogen [18]. Highly significant control of P. digitatum on inoculated 'Ambersweet' orange fruits by exposure to vapour heat (steam) at 55°C for 25 and 35 minutes; also, at 60° C for 30 to 40 minutes, respectively has also been reported [3].

The 'Kings' orange fruit which is more susceptible to deterioration than Ambersweet [2, 3] is presently investigated for potential shelf-life extension at ambient storage condition. The quality will be assessed after steam treatment at the temperature – time points reported advantageous to Ambersweet orange fruits [3]. The results should provide insight into the possible adoption of the most effective steam treatment for routine processing of this orange cultivar before storage. This could give opportunity for convenient and economic control of multiple fungal pathogens which usually occur on harvested plants including fresh fruits; and also, on the same pathogen occurring on different cultivars of same species. The results of the investigation should also contribute to available information which will aid the design and operation of pre-storage heat treatment facilities for Citruses, and possibly other types of fresh fruits particularly where such are still lacking.

II. Materials and Methods

A. Source And Preparation Of Fruits

Mature Kings' orange fruits were harvested from the same parent stock in an orchard and treated within 24 hours of harvest. Fruits of nearly uniform rind colour were washed with potable water, and then surface disinfected by immersing in 0.385% m/v sodium hypochlorite solution for 10 minutes. After draining dry, they were subjected to steam treatment in a Gallenkamp water bath. They were separately heated at 55 °C, 60 °C for 25 and 35 minutes at each temperature. Each treatment lot consisted of thirty fruits. The fruits were then kept at 26 °C and 90 – 95% relative humidity in disinfected plastic boxes with close fitting lids.

B. Rot Incidence

The total number of fruits that showed rot symptoms as browning or blackening with softening, mycelium presence as wooly growths, aggregation of coloured powdery spores on the surface, tissue breakdown evidenced as oozing of fluid were noted every week. They were removed from storage to prevent the spread of infection. Incidence of rot was expressed as fraction of the original number of fruits in each box. The cummulative percentage rot occurrence at the end of storage was also calculated. Disease types were identified by noting the symptoms [10, 20, 24, 34].

C. Changes In Weight Of Fruits

The initial fresh weight of individually labelled fruits was taken at the beginning of storage. Individual weight of three fruits which remained disease free in each treatment lot were also taken weekly. The differences in weight, were used to calculate the percentage weight loss from the original weight.

D. Estimation Of Fruit Juice Volume

Juice was separately extracted from disease free fruits in each treatment lot with the aid of a manual juice extractor. It was then filtered through muslin cloth. The volume from each fruit was estimated in a measuring cylinder, means were calculated and expressed in milliliters (ml). This was done at the beginning of storage and weekly thereafter.

E. Measurement Of Juice pH

The pH of freshly extracted, filtered fruit juice in each treatment was measured at 28 °C using a portable pH meter. This was done weekly during storage.

F. Determination Of Juice Titratable Acid (TA)

The titratable acid content of fruit juice was calculated and expressed as amount of citric acid (g/100ml juice) after titration against 0.1N NaOH [7].

G. Estimation Of Juice Total Soluble Solids (TSS) Content

The TSS of freshly extracted juice was estimated using a hand refractometer and expressed as ° Brix. The measurements were taken weekly on juice obtained from fruits which remained disease free.

H. Statistical Analysis Of Data

The data obtained were subjected to one – way analysis of variance using SPSS software. Where significant, the means were compared by Tukey's HSD test at $\alpha=0.05$ to determine differences between treatments on weight changes, juice volume, pH, titratable acid and TSS.

III. Results

Steam treated fruits showed rot symptoms from the first week of storage while control fruits showed the same symptoms only from the second week. Weekly rot incidence ranged from 3.3 to 13.3%. The lowest incidence throughout storage was observed among control fruits. All steam treated fruits except those exposed to 60 °C for 25 minutes had cummulative rot incidence of 43% at the end of five weeks while control was 33% and those exposed to 60 °C for 25 minutes had approximately 37% (Table 1). The diseases observed on fruits were the green mould by *Penicillium digitatum*, stem-end rot by *Lasiodiplodia theobromae* and black rot by *Aspergillus niger*.

TABLE I. Incidence Of Rot On Orange Fruits (*Citrus Sinensis* cv. *Nobilis*) Exposed To Steam And Stored At 26°C

Treatment (°C-minutes)	**Period of storage (weeks) / Number (Percentage) of decayed fruits**					
	1	**2**	**3**	**4**	**5**	**Cumulative**
Control	0	2(6.66)	3(9.99)	3(9.99)	2(6.66)	10(33.33)
55 – 25	2(6.66)	2(6.66)	2(6.66)	4(13.33)	3(9.99)	13(43.33)
55 – 35	2(6.66)	2(6.66)	4(13.33)	3(9.99)	2(6.66)	13(43.33)
60 – 25	1(3.33)	2(6.66)	2(6.66)	3(9.99)	3(9.99)	11(36.66)
60 – 35	2(6.66)	3(9.99)	3(9.99)	3(9.99)	2(6.66)	13(43.33)

Figures are numbers of rotten fruits with percentage rot occurrence in parentheses

The fruits lost weight during storage but there were no significant differences between treatments before the fifth week. At the fifth week, those treated at 55 °C for 35 minutes showed the least weight loss being 3.77% while the highest was 6.89% from fruits exposed to steam at 60 °C for 25 minutes. Statistically significant differences were obtained among steam treated fruits but not in comparison with control. Cummulative weight loss was between 11.06 and 16.44 % across treatments including control. The lowest cummulative loss occurred from fruits treated at 60 °C for 35 minutes and the highest from fruits exposed to 55 °C for 25 minutes (Table 2).

TABLE II. WEIGHT LOSS FROM ORANGE FRUITS (CITRUS SINENSIS CV. NOBILIS) EXPOSED TO STEAM TREATMENT AND STORED AT 26°C

Treatment (°C-minutes)	Period of storage (weeks) / Mean percentage weight loss					
	1	2	3	4	5	Cummulative
Control	1.02±0.13[a]	0.69±0.35[a]	1.68±0.19[a]	2.70±0.71[a]	5.40±0.55[ab]	11.49±1.93
55 – 25	1.91±0.67[a]	1.29±0.54[a]	2.36±0.55[a]	4.03±0.86[a]	6.85±0.36[b]	16.44±2.98
55 – 35	0.92±0.10[a]	1.32±0.20[a]	2.13±0.23[a]	3.22±0.75[a]	3.77±0.79[a]	11.36±2.07
60 – 25	0.93±0.08[a]	1.49±0.18[a]	2.27±0.38[a]	2.93±0.47[a]	6.89±0.40[b]	14.51±1.51
60 – 35	0.97±0.15[a]	1.76±0.46[a]	1.23±0.41[a]	2.51±0.22[a]	4.59±0.18[ab]	11.06±1.42

Figures are means of three replicates ± standard error (SE) of the mean. Means with the same alphabet(s) in a column are not significantly different from each other (p>0.05) by Tukey's HSD test.

The juice volume did not change significantly with treatment. It however decreased with storage in fruits treated at 50 °C in the first four weeks of storage after which there was only a slight increase. Among fruits treated at 60 °C, there were initial increases in juice volume in the first two weeks before decreasing up to week 4. This was followed by another increase again in week 5. The juice volume of control fruits continuously decreased up to week 3, then increased slightly in week 4 before another decrease at week 5 (Table 3).

TABLE III. JUICE VOLUME OF ORANGE FRUITS (CITRUS SINENSIS CV. NOBILIS) EXPOSED TO STEAM AND STORED AT 26°C

Treatment (°C-minutes)	Period of storage (weeks) / Mean juice volume (ml) per fruit				
	1	2	3	4	5
Control	44.0±2.64[a]	47.0±4.50[a]	44.6±1.20[a]	45.0±5.29[a]	36.3±2.40[a]
55 – 25	52.0±5.00[a]	50.0±8.50[a]	44.3±3.48[a]	31.6±7.68[a]	34.6±8.08[a]
55 – 35	53.6±4.37[a]	48.0±6.50[a]	44.3±7.96[a]	40.3±3.84[a]	42.6±4.05[a]
60 – 25	51.3±3.84[a]	60.6±13.6[a]	40.6±5.20[a]	35.6±2.60[a]	42.6±3.84[a]
60 – 35	50.0±5.03[a]	53.0±5.85[a]	51.3±6.69[a]	43.0±1.00[a]	44.0±8.08[a]

Figures are means of three replicates ± standard error (SE) of the mean. Means with the same alphabet(s) in a column are not significantly different from each other (p>0.05) by Tukey's HSD test.

There were changes in the pH with treatment. At the first week of storage, control fruits had the highest acidity. Fruits treated at 55 °C for 35 minutes showed statistically significant difference from the control as they had lower acidity. Results at the second week were similar to first week observations, but fruits treated at 55 °C for 25 minutes had the lowest acidity. At the third and fourth weeks, there were no statistically significant differences in pH in all treatments while at the fifth week, there were significant differences among fruits treated at 60 °C for 35 and 25 minutes which had the lowest and highest acidity respectively. Juice pH ranged between 3.37 and 3.72 throughout storage showing little variation (Table 4).

TABLE IV. PH OF JUICE FROM ORANGE FRUITS (CITRUS SINENSIS CV. NOBILIS) TREATED WITH STEAM AND STORED AT 26°C

Treatment (°C-minutes)	Period of storage (weeks) / Mean pH of juice from fruits				
	1	2	3	4	5
Control	3.43±0.12[a]	3.48±0.33[a]	3.72±0.05[a]	3.56±0.03[a]	3.44±0.02[ab]
55 – 25	3.50±0.04[ab]	3.64±0.14[b]	3.70±0.07[a]	3.53±0.04[a]	3.42±0.02[ab]
55 – 35	3.61±0.03[b]	3.57±0.50[ab]	3.53±0.08[a]	3.51±0.07[a]	3.41±0.02[ab]
60 – 25	3.54±0.17[ab]	3.61±0.08[ab]	3.53±0.03[a]	3.61±0.04[a]	3.51±0.04[b]
60 – 35	3.54±0.05[ab]	3.58±0.02[ab]	3.51±0.04[a]	3.44±0.01[a]	3.37±0.02[a]

Figures are means of three replicates ± standard error (SE) of the mean. Means with the same alphabet(s) in a column are not significantly different from each other (p>0.05) by Tukey's HSD test.

The titratable acid values of the fruit juices were not significantly different with treatment until the fifth week of storage when fruits exposed to steam at 55 °C for 25 and 35 minutes showed the greatest acidity and those treated at 60 °C for 25 minutes had the lowest acidity. The weekly TA values of control fruits were mostly between those of treated fruits (Table 5).

TABLE V. TITRATABLE ACID OF JUICE FROM ORANGE FRUITS (CITRUS SINENSIS CV. NOBILIS) EXPOSED TO STEAM AND STORED AT 26°C

Treatment (°C-minutes)	Period of storage (weeks) / g Citric acid per100ml juice from fruits				
	1	2	3	4	5
Control	0.64±0.04[a]	0.53±0.04[a]	0.74±0.02[a]	0.73±0.01[a]	0.65±0.02[ab]
55 – 25	0.54±0.02[a]	0.68±0.15[a]	0.67±0.07[a]	0.70±0.01[a]	0.71±0.29[b]
55 – 35	0.64±0.02[a]	0.53±0.03[a]	0.77±0.04[a]	0.67±0.02[a]	0.71±0.14[b]
60 – 25	0.53±0.08[a]	0.55±0.08[a]	0.63±0.14[a]	0.68±0.02[a]	0.57±0.02[a]
60 – 35	0.54±0.09[a]	0.48±0.04[a]	0.63±0.17[a]	0.81±0.08[a]	0.63±0.02[ab]

Figures are means of three replicates ± standard error (SE) of the mean. Means with the same alphabet(s) in a column are not significantly different from each other (p>0.05) by Tukey's HSD test.

There were no statistically significant differences in the total soluble solids content of fruit juices with treatment. The TSS was however highest in juice from control fruits in the first week of storage. Although there were slight fluctuations during storage. There was also substantial increase with time at all treatments. The lowest TSS was obtained in juice from fruits exposed to steam at 60 °C for 35 minutes in the first week and it remained the lowest throughout storage except at the second week. The highest was measured in fruits treated at 55 °C for 25 minutes in the last week of storage (Table 6).

IV. Discussion

The results of this study have shown that steam treatment had no significant advantage in controlling rot on this cultivar of Citrus orange fruits. This is because observed weekly rot incidences on uninoculated fruits were about the same in steam heated and non-heated samples. This contradict earlier reports [3, 5, 34] that heat treatment was advantageous in controlling rot on inoculated 'Ambersweet', 'Shamouti', and 'Valencia' oranges. Reduced disease severity by P. digitatum on naturally infected and artificially inoculated oranges at ambient and refrigerated storage after curing at 33 °C for 65 minutes have also been reported [26]. Earlier report of reduced severity of green mould at 28 °C storage following steam treatment at 50 °C for 30 minutes was made [1]. Cultivar differences may however, be responsible for the presently observed deviations from earlier reports.

The slightly higher decay incidence among heated fruits might also be because the 'Nobilis' orange fruit peel is less thick (measurements not taken) and smoother in texture in comparison with 'Ambersweet' fruit peel. The relatively thin 'Nobilis' peel likely permitted faster and more serious rind injury during heating leading to greater fungal decay. The nutrients and peel oils released as a result of injury aided fungal spore germination and colonization of fruits producing decay symptoms. Penicillium digitatum spores germinate only in the presence of moisture and volatiles from Citrus peel [9, 11]. It was reported again that disease by P. digitatum on Citruses occur only in the presence of rind wounds [20, 25]. Lasiodiplodia sp. may also infect Citrus fruits only through openings at the stem end [37]. The occurrence of Lasiodiplodia theobromae rot support report that the fungus Botryodiplodia theobromae (Lasiodiplodia theobromae) occurred on three species of Citrus in South Western Nigeria [4]. The present observation of higher rot occurrence among heated fruits is also contrary to earlier reports [21] that Citrus lemon produced antifungal compounds against P. digitatum at wound sites during heating at 36 °C, though storage was for 24h only at 17 °C. The insignificant difference observed in percentage rot occurrence between steam heated and control fruits in this investigation emphasize the fact that the rot occurrence may not be attributable to heat injury alone. It was also probably due to the moderate storage temperature which favoured growth of decay fungi and was only exacerbated by the presence of rind injury on heated fruits.

The observed higher weight loss after 25 minutes heating at both temperatures in comparison to the 35 minutes heating, suggest that longer heating could be advantageous in preserving appearance because there was less shrinkage resulting from moisture loss. The longer residence time in the moist heat chamber probably allowed the replacement of lost moisture to fruit especially, because the saturation of the heating chamber with water vapour increased with time. This allowed condensation on fruit surfaces, likely slowing down further moisture loss by evaporation from fruits which normally occur as a consequence of vapour pressure deficit in the atmosphere surrounding a commodity. Longer heating of fruits also, likely permitted more release of fluid materials including oils which on cessation of heat application, solidified around the pores on the peel, reducing moisture and fluid loss [13, 33, 36]. This is further supported by the observations on juice volumes which were mostly insignificantly higher at the more severe heat treatment points. Earlier reports on other Citruses however, indicate that weight changes due to heat treatment could vary [29, 30, 31]. The little variation presently observed in juice volume may be due to differences in fruit size rather than the treatments applied. This therefore suggests that longer heating may better preserve the quality and acceptability of fruit. The present observation however contradicts earlier explanation [5] that temperature only, rather than in combination with duration of heating may cause prohibitive damage to Citrus fruit during pre-storage heat treatment.

The observed slightly significant difference in juice acidity measured as pH and titratable acid only in the fifth week of storage, indicate that heating did not affect this quality parameter, but storage probably did, and then only slightly. This is similar to reports on mandarins [17]. Acidity reduction in cured 'Valencia' oranges has been reported [23]. Acidity reduction due to heating of fruits at higher temperature for shorter time which coincide with the treatment at which highest weight loss was observed indicate that acidity is affected not only directly by the amount of water and organic acids in juice vesicles, but also by other chemical constituents, probably mainly the carbohydrates (soluble and insoluble solids). The total soluble solids contents being highest in fruits heated at 60 °C for 25 minutes by the fourth week and which remained considerably high in the fifth week also support this. Also, the TSS which remained relatively insignificantly different due to heating and storage is indicative of the fact that the presently applied steam treatment points, and storage length may not have seriously affected this quality attribute. Insignificant change in soluble solids content of 'Tarocco' blood oranges during storage for two months at 8 °C followed by three days of shelf-life at 20 °C was also observed [6]. Similar observations were also reported for 'Valencia' orange [23].

Overall, heat treatment using steam had no significant undesirable effect on whole 'Nobilis' orange fruit and juice quality. The presently observed effects on internal quality indicate that heating may contribute to enhancement of flavour and acceptability rather than deterioration. The slightly higher cummulative rot percentage obtained among heated fruits in comparison with control unlike other varieties of orange fruits previously reported [2, 3, 5] is negligible. This is because it was only 3 - 10% at the end of five weeks under ambient storage. Thus, this shows the appreciable tolerance of Citrus sinensis cv. Nobilis fruits to steam treatment at the presently tested temperature–time points. Further studies may focus on the factors responsible for these relatively unaltered internal quality attributes even with the severe heat treatment. This may affect the adoption of the technology by fruit packers and acceptability of the products by consumers. The time to harvest on attainment of maturity before steam treatment, and storage may also need to be investigated as this may affect fruit response to heat treatment [13, 27].

V. Conclusions

The results of this study in combination with previous observations on 'Ambersweet' orange, indicate that the presently reported pre-storage heat treatments may be applied to different cultivars of sweet orange fruits without significant changes in quality of produce during subsequent storage. Other species of *Citrus* may also be investigated under the same conditions to ascertain the possibility of developing the same type of heat treatment for Citruses in general, and possibly other types of soft fruits; also, for commercial operations. The potential economic advantage of multi produce treatment, and convenience, with the environmental protection offered by this technology should be considered for routine operation in packing houses of fruits and vegetables prior to storage and distribution.

Acknowledgment

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. The authors however acknowledge the technical assistance provided in the laboratory by both Mrs Toyin Ojo, the Chief Technologist, and Mrs Adenike Akindolani in the Department of Biology of the University.

References

[1] A.T. Aborisade, "Heat treatment against the green mould on sweet orange (Citrus sinensis L. Osbeck) fruits at tropical ambient storage," Acta Horticulturae, vol. 1079, pp. 319–323, 2014.

[2] A.T. Aborisade and A.A. Ajibade, "Effect of pre-storage curing on storage life, internal and external qualities of sweet orange (Citrus sinensis)," Revista Brasileira de Fruticultura, vol. 32(3). doi:10.1590/s0100-29452010000300034. ISSN 0100-2945, 2010.

[3] A.T. Aborisade and O.O. Elufisan, "Extension of shelf life of Penicillium digitatum infected sweet Oranges by vapour heat treatment," Acta Horticulturae, vol. 1325, pp. 41-46, 2021. https://doi.org/10.17660/ActaHortic.2021.1327.7

[4] V.A. Adisa and A.O. Fajola, "Postharvest fruit rots of three species of Citrus in South Western Nigeria,". Indian Phytopathology, vol. 35, pp. 595–603, 1982.

[5] S. Ben – Yehoshua, B. Shapiro and R. Moran, "Individual seal packaging enables the use of curing at high temperatures to reduce decay and heal injury of Citrus fruits," HortScience, vol. 22(5), pp. 777–783, 1987.

[6] M. Buccheri, M. Grassi, G. Bianchi, F. Lovati, M. Vanoli … D. Croce, "Postharvest physiology, nutritional quality and aroma profile of 'Tarocco' blood orange fruit (Citrus sinensis L. Osbeck),". Acta Horticulturae, vol. 1079, pp. 291–298, 2014.

[7] S. D'Aquino, A. Piga, M. Agabbio and T.G. McCollum, "Film wrapping delays ageing of 'Minnela' tangelos under shelf-life conditions," Postharvest Biology and Technology, vol. 14, pp. 107-116, 1998.

[8] E. Dreassi, A. Zanfini, A.T. Zizzari, C. La Rosa, M. Botta, G. Corbini, "Lc/Esi/Ms/Ms determination of postharvest fungicide residues in citrus juices," LWT – Food Science and Technology, vol. 43(9), pp. 1301 – 1306, 2010. https://doi.org/10.1016/j.lwt.2010.04.010

[9] S. Droby, A. Eick, D. Macarisin, L. Cohen, G. Rafael … R. Shapira, "Role of citrus volatiles in host recognition, germination, and growth of Penicillium digitatum and Penicillium italicum," Postharvest Biology and Technology, vol. 49(3), pp. 386–396, 2008.

[10] J.W. Eckhert, "Postharvest diseases of Citrus fruits," Outlook on Agriculture, vol. 9(5), 1978. https://doi.org/10.1177/003072707800900506

[11] J.W. Eckert, M. Ratnayake, "Role of volatile compounds from wounded Oranges in induction of germination of Penicillium digitatum conidia," Phytopathology, vol. 84, pp. 746-750, 1994.

[12] A. Erasmus, C.L. Lennox, J.L. Smilanick, K. Lesar and P.H. Fourie, "Imazalil residue loading and green mould control on Citrus fruit as affected by formulation, solution pH and exposure time in aqueous dip treatments," Postharvest Biology and Technology, vol. 77, pp. 43 – 49, 2013. https://doi.org/10.1016/j.postharvbio.2012.11.001

[13] E. Fallik, S. Alkalai-Tuvia and D. Chalupowicz, "Hot water rinsing and brushing of fresh produce as an alternative to chemical treatment after harvest – the story behind the technology," Agronomy, vol. 11(8), 1653, 2021.

[14] C.F. Forney, G.S. Bezanson, T.C. Ells, L. Fan and D.I. LeBlanc, "Impact of heat sanitation of fresh whole cantaloupe on fruit quality and volatile metabolism," Acta Horticulturae, vol. 1079, pp. 145 – 151, 2015.

[15] F. Gasser, C. Good and A. Naef, "Hot water treatment of selected organic apple and Pear cultivars," Acta Horticulturae, vol. 1079, pp. 391 – 396, 2015.

[16] M.A. Gatto, A. Ippolito, L. Sergio and D. Di Venere, "Extracts from wild edible herbs for controlling postharvest rots of fruit and vegetables," Acta Horticulturae, vol. 1144, pp. 349 – 354, 2016. https://doi.org/10.17660/ActaHortic.2016.1144.51

[17] D.B. Queb-Gonzalez, A. Lopez-Malo, M.E. Sosa-Morales and R. Villa-Rojas, "Postharvest heat treatments to inhibit Penicillium digitatum growth and maintain quality of mandarin (Citrus reticulata Blanco)," Heliyon, vol. 6(1), e03166. https://doi:10.1016/j.heliyon.2020.e03166,2020.

[18] Y. Huang, B.J. Deverall and S.C. Morris, "Postharvest control of green mould on orange by a strain of Pseudomonas glathei and enhancement of its biocontrol by heat treatment," Postharvest Biology and Technology, vol. 5, pp. 129–137, 1994.

[19] S.V. Irtwange, "Hot water treatment: a non-chemical alternative in keeping quality during postharvest handling of Citrus fruits," Agricultural Engineering International: CIGR Ejournal, vol. 8(5), pp. 1 – 10, 2006.

[20] M. Ismail and J. Zhang, "Post-harvest Citrus diseases and their control. In: Post-harvest Citrus disease control," Outlooks on pest Management, pp 29–35, 2004. Doi:10.1564.

[21] J.J. Kim and S. Ben–Yehoshua, "Histological detection of phytoalexin scoparone from heat-treated and UV – illuminated lemon fruits after inoculation with Penicillium digitatum," Plant Pathology, vol. 17(5), pp. 271–275, 2001.

[22] P.A. Moscoso-Ramirez and L. Palou, "Potassium silicate: a new organic tool for the control of citrus postharvest green mold," Acta Horticulturae, vol. 1144, pp. 287 – 291, 2016.

[23] C. Nunes, J.M. Garcia, T. Manso, R. Torres, M. Olmo, J. Usall, "Effects of postharvest curing treatment on quality of Citrus fruit," Vegetable Crops Research Bulletin, vol. 66, pp. 213–220, 2007. doi:10.2478/v10032-007-0024-6.

[24] L. Palou, J.L. Smilanick, J. Usall and I. Vinas, "Control of postharvest blue and green molds of Oranges by hot water, sodium carbonate, and sodium bicarbonate," Plant Disease, vol. 85, pp. 371–376, 2001.

[25] L. Palou, "Penicillium digitatum, Penicillium italicum (Green mold, blue mold)", In: Bautista S-Banos (Ed). Postharvest decay – Control strategies. Academic Press, pp. 45–102, 2014.

[26] P. Plaza, J. Usall, R. Torres, N. Lamarca, A. Asensio, I. Vinas, "Control of green and blue mould by curing on oranges during ambient and cold

storage,”. Postharvest Biology and Technology, vol. 28(1), pp. 195–198, 2003. https://doi.org/10.1016/S0925-5214(02)00127-8

[27] P. Plaza, A. Sanbruno, J. Usall, N. Lamarca, R. Torres … V. Immaculada, “Integration of curing treatments with degreening to control the main postharvest diseases of ‘Clementine’ mandarins,”. Postharvest Biology and Technology, vol. 34, pp. 29 – 37, 2004.

[28] R. Porat, A. Daus, B. Weiss, L. Cohen, E. Fallik, S. Droby, “Reduction of postharvest decay in organic citrus fruit by a short hot water brushing treatment,”. Postharvest Biology and Technology, vol. 18(1), pp. 151–157, 2000. https://doi.org/10.1016/S0925-5214(99)00065-4

[29] V. Rodov, S. Ben-Yehoshua, R. Albagli, D.Q. Fang, “Reducing chilling injury and decay of stored citrus fruit by hot water dips,” Postharvest Biology and Technology, vol. 5, pp. 119 – 127, 1995.

[30] M. Schirra, G. D’hallewin, “Storage performance of Fortune mandarins following hot water dips,” Postharvest Biology and Technology, vol. 10, pp. 229 – 238, 1997.

[31] M. Schirra, M. Agabbio, G. D’hallewin, M. Pala, R. Ruggiu, “Response of Tarocco oranges to picking date, postharvest hot water dips, and chilling storage temperature,” J Agric. Food Chem, vol. 45, pp. 3216 – 3220, 1997.

[32] M. Schirra, G. Barbera, G. D’Hallewin, P. Inglese and T. La Mantia, “Storage response of Cactus pear fruit to CaCl2 preharvest spray and postharvest heat treatment,” Journal of Horticultural Science, vol. 72(3), pp. 371–377, 1997.

[33] M. Schirra, G. D’hallewin, S. Ben–Yehoshua and E. Fallik, “Host – pathogen interactions modulated by heat treatment,” Postharvest Biology and Technology, vol. 21, pp. 71 – 85, 2000.

[34] JL. Smilanick, D. Sorensen, M. Mansour, J. Aieyabei and P. Plaza, “Impact of a brief postharvest hot water drench treatment on decay, fruit appearance and microbe populations of California lemons and oranges,” Hortechnology, vol. 13, pp. 333 – 338, 2003.

[35] N. Tzortzakis, “Gaseous ozone- enrichment for the preservation of fresh produce,” Acta Horticulturae, vol. 1079, pp. 273 – 279, 2015.

[36] M.H. Williams, M.A. Brown, M. Vesk and C. Brady, “Effect of postharvest heat treatments on fruit quality, surface structure, and fungal disease in Valencia oranges,” Australian Journal of Experimental Agriculture, vol. 34(8), pp. 1183 – 1190, 1994.

[37] J. Zhang, “Lasiodiplodia theobromae in Citrus fruit (Diplodia stem – end rot) In: Postharvest Decay–Control strategies,” Academic Press. pp. 309-335, 2014. https://doi.org/10.1016/B978-0-12-411552-1.00010-7.