IJAFLS
e-ISSN: 2602-4381
International Journal of Agriculture, Forestry and Life Sciences
Original Article Open access Int J Agric For Life Sci (2021) 5(1): 122-128

Postharvest Hot Air Treatment to Maintain Fruit Quality of Nanfeng Mandarins During Storage

Qiang Huang[1], Ruopeng Yang[1], Chuying Chen[1], Chunpeng Wan[1] and İbrahim Kahramanoğlu[2*]

[1]Jiangxi Key Laboratory for Postharvest Technology and Nondestructive Testing of Fruits & Vegetables/ Collaborative Innovation Center of Postharvest Key Technology and Quality Safety of Fruits & Vegetables in Jiangxi Province, College of Agronomy, Jiangxi Agricultural University, Nanchang 330045, China;
[2]Faculty of Agricultural Sciences and Technologies, European University of Lefke, Gemikonağı, Northern Cyprus, via Mersin 10 Turkey
***Correspondence:** ikahramanoglu@eul.edu.tr*

Abstract

Nanfeng mandarins are very sensitive to postharvest storage mainly because of fungal attracts. One of the most effective non-chemical handling practices for maintaining storage quality is the heat treatment. In general, heat treatment i) improves products resistance by activating some enzymes and/or ii) produces reactive oxygen species (ROS) in fungus cells and damage them. However, the heat temperature and duration are highly variable among the species and cultivars; and according to authors knowledge, there is not any information about heat treatment on Nanfeng mandarins. In this case, present study aimed to test the effects of different hot air flow (HAF at 37 °C) durations on the postharvest quality of Nanfeng mandarins. Studies were conducted in two consecutive phases. In the first phase, three different HAF durations (24 h, 36 h and 48 h) were tested together with un-treated control fruits for 100 days of storage. Results of first phase studies suggested that the 36 h of HAF provides best efficacy for controlling fruit decay and reducing weight loss. Then, this treatment was tested again together with control treatment and quality measurements were done regularly (10, 20, 30, 40, 60, 80 and 100 days) for analysing some quality characteristics and enzymatic activities. According to the results obtained, the HAF treatment was comparatively effective in keeping soluble contents, sugar, vitamin C and acidity. The main mechanisms behind this success were found to be the reduced respiration rate and increased polyphenol oxidase (PPO) enzyme activity. Shortly, results suggested that the HAF for 36 h is effective in keeping the storage quality of Nanfeng mandarins.

Key words: Hot air flowing; Weight loss; Fruit decay; Biochemical changes; Enzymatic activities

INTRODUCTION

Citrus fruits cover the most produced and consumed fruit species in the world. Total citrus production was reported as 143.5 M tonnes in 2019 and was followed by bananas (116.7 M tonnes) and apples (87.2 M tonnes). Among the citrus group, oranges cover 54.8% of the production and mandarins represent 24.7%. China is the main mandarin producer in the world, where the total production of China (19.8 M tonnes) represents the 56.1% of worlds mandarin production (FAO, 2021). Mandarin fruits are very beneficial for human health and are being preferred by the consumers mainly because of their high nutrients, vitamins and phenolic contents (Connor et al., 2002). Mandarin fruits are also among the most important export fruits. However, their storability is not so long, mainly because of weight loss and fungal decay (Henriod, 2006).

Cite this artile as:
Huang Q., Yang R., Chen C., Wan C. and Kahramanoğlu İ. 2021. Postharvest Hot Air Treatment to Maintain Fruit Quality of Nanfeng Mandarins During Storage. *Int. J. Agric. For. Life Sci.*, 5(1): 122-128.
ORCID and Mail:
Q. Huang: 0000-0001-5528-5099 (hp13767144404@163.com); R. Yang: 0000-0002-4983-3148 (yrp_biology2@126.com);
C. Chen: 0000-0003-2085-1577 (cy.chen@jxau.edu.cn); C. Wan: 0000-0001-6892-016X (chunpengwan@jxau.edu.cn);
İ:Kahramanoğlu: 0000-0002-6074-6395 (ibrahimcy84@yahoo.com)
Received: 04.06.2021 **Accepted:** 27.06.2021 **Published:** 27.06.2021
Year: 2021 **Volume:** 5 **Issue:** 1 (June)
Available online at: http://www.ijafls.org - http://dergipark.gov.tr/ijafls

Moreover, storage conditions are known to significantly affect fruits phenolic contents, nutrition quality and sugar/acid ratio (Sridi et al., 2014). However, most important storage problem of mandarins is the fungal decay, which can reach up to (and sometimes more of) 50% (Feliziani and Romanazzi, 2013). Fungicides i.e. imazalil and thiabendazole are effective in preventing fungal decay (Kinay et al., 2007), but not preferred by consumers due to increased concern of the consumers against agro-chemicals (Suleria et al., 2015) and also fungicides are not effective in keeping physiological quality of the mandarins. Cold storage (at 5 to 8 °C) (Kader and Arpaia, 2002), covering with edible (made from plant extracts or lipids) coatings (Chen et al., 2019; Kahramanoğlu and Usanmaz, 2019; Wan et al., 2021) and curing with heat treatment (Kahramanoğlu et al., 2020a; Kahramanoğlu et al., 2020b; Wan et al., 2020; Gao et al., 2021). As the physiological response of the fruits to the storage conditions and fungal attacks, activity of some enzymes increase and helps to extends storage duration. For example; superoxide dismutase (SOD) is important for alleviating lipid peroxidation (Sels et al., 2008) and polyphenol oxidase (PPO) is important for protecting fruits against fungal pathogens (Gao et al., 2018). Furthermore, current knowledge in the published literature suggests that the mechanism of edible coatings and/or curing with heat treatment may be related with their effects of those enzymes' activity (Yun et al., 2013; Atrash et al., 2018). Up to now, most of the published studies for curing with heat treatment had been carried with hot water treatment (Erkan et al., 2005; Yun et al., 2013; Alvindiaet al., 2015; Atrash et al., 2018; Zhang et al., 2019) while the studies with hot air treatment/flow are limited (Wang et al., 2015; Huan et al., 2017; Wei et al., 2018). Therefore, present study was conducted with an aim of testing the effects of hot air flow (HAF) on the storage quality of Nanfeng mandarin fruits.

MATERIALS AND METHODS

Materials

Mature Nanfeng mandarins (*Citrus reticulata* Blanco cv. 97-2) were used in present study. The fruits were harvested in November 2015 and November 2016 from an orchard located in Jiangxi, China. The fruit weight during harvest was about 40-50 g and the colour according to the citrus colour index was 2.5-3.2.

Methods

These studies were conducted in two consecutive phases. In the first phase, three different HAF (at 37 °C) durations (24 h, 36 h and 48 h) were tested together with un-treated control fruits for 100 days of storage. This first phase was done to determine the optimal flow duration for Nanfeng mandarins. Three replications (each with 80 fruits) were adjusted to each of these 4 different treatments. As mentioned above, this first phase of the studies was conducted in 2015. The main aim was to determine the effects of these four treatments on the weight loss and decay rate. Before the experiments, weights of each fruit ware noted for further calculations of the weight loss. Then each of the fruits were film-packaged and kept at 6 ± 0.5 °C with a relative humidty (RH) of 85-90% for 100 days. At the end of this duration, the decay rate and weight loss were measured for each treatment. Results of this first phase suggested that the 36 h of HAF provides best efficacy for controlling fruit decay and reducing weight loss. Then, this treatment was used in the second phase of the studies.

In the second phase of the studies, the HAF (37 °C) for 36 h was tested again together with control treatment (20 °C) and quality measurements were done regularly (10, 20, 30, 40, 60, 80 and 100 days) for analysing some quality characteristics and enzymatic activities. The RH was adjusted to 85-95% during HAF treatment. After HAF treatment, each individual fruit, both from HAF and control, were film-packed and stored at 6 ± 0.5 °C and 85-90% RH. Similar with first phase experiments, each treatment was composed of 3 replications; and each replication was composed of 70 fruits. At each of the measurement point, 10 fruits from each replication was randomly taken out from the storage rooms and following quality parameters were measured:

- Total soluble solids (TSS) content as % of each fruit was determined with the RA-250WE Brix-meter (Atago, Tokyo, Japan).
- Total sugar content of each fruit was measured by following the anthrone colorimetric method (as %).
- Titratable acidity was measured by following the standard titration method with 0.1 M NaOH.
- Vitamin C (ascorbic acid) contents of mandarin fruit juices were determined by titration with 2,6-dichlorophenol indophenol.
- Respiration rate was assessed with the method reported by Chen et al. (2019) by measruing the CO2 production as mg kg^{-1} h^{-1}.
- Malondialdehyde (MDA) contents of each replication was assessed by following the method of Hodges et al. (1999) and expressed as mmol g−1 frozen weight.
- SOD enzyme activity was determined with the method of Ballester et al. (2006) and presented as U min^{-1} g^{-1}.
- Peroxidase (POD) enzyme activity was then calculated with the method of Wan et al. (2020) and expressed as U min^{-1} g^{-1}.
- Finally, PPO enzyme activity was assessed according to the formula of Kahramanoğlu et al. (2020) and presented as U h^{-1} g^{-1}.

Data analysis

Raw data of the above-mentioned quality parameters were firstly summed and analysed with Microsoft Excel. Then, the data was transferred to SPSS 22.0 to perform analysis of variance test. In the case of statistical difference among the treatments, a further test (Duncan's multiple range test for more than 2 treatments and t-test for 2 treatments) was performed to do statistical separation (at $P < 0.05$).

RESULTS

Relationship between HAF and physical quality parameters of Nanfeng mandarins

After 100 days of storage, significant differences were determined among the decay rate and weight loss of the Nanfeng mandarins treated with different durations of HAF. At this point, increasing the HAF duration from 24 h to 36 h was found to have positive effect on the prevention of weight loss and decay rate (Figure 1.). However, increasing the HAF duration from 36 h to 48 h was noted to have negative effect. Thus, the best treatment for the prevention of weight loss and fungal decay was found to be HAF at 37 ºC for 36 h. After 100 days of storage, total weight loss was found to be 5.25% at the un-treated control fruits; while the fruits treated with be HAF at 37 ºC for 36 h was only 3.62%. Similar to the weight loss, the decay rate was 27% at the control fruits and only 6% at the HAF treated fruits.

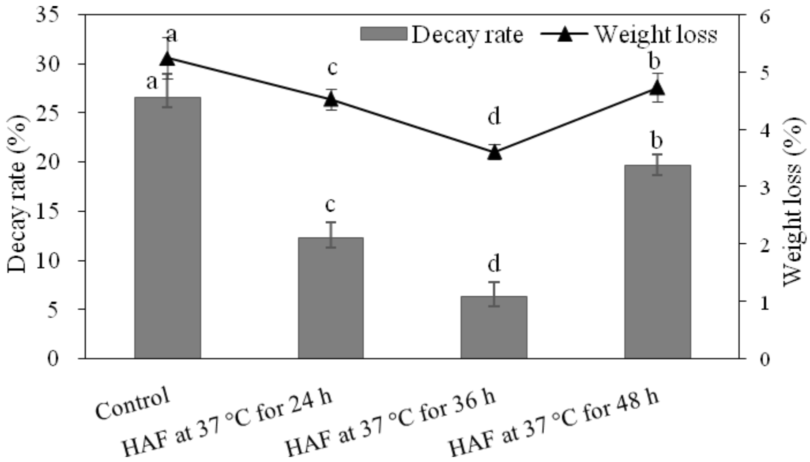

Figure 1. Effect of different HAF (24, 36, and 48 h) treatments on decay rate and weight loss of Nanfeng mandarin stored at 6 °C for 100 days.

Relationship between HAF and bio-chemical quality parameters of Nanfeng mandarins

According to the results obtained, both TSS and total sugar increased during the initial phases of storage and then decreased. However, the HAF treatment was found to significantly increase both TSS and total sugar as compared with the un-treated control fruits (Figure 2.). The vitamin C content was also noted to have a similar trend with the TSS and total sugar. The HAF treatment was again found to be effective in this bio-chemical quality parameter. Thus, the fruits which treated with HAF had higher VC content than the others. Results showed that 30 days is critical for TSS and VC, while both bio-chemical parameters increased during the first 30 days of storage. Hereafter, both of them decreased, while HAF was effective in keeping these parameters higher than control. The final TSS and total sugar of the un-treated control fruits had been noted to be lower than the initial values, where the HAF treated fruits had slightly higher than the initial values. Similar results had been observed for VC, but both the HAF treated and un-treated fruits' VC were lower than the initial values. The change in TA content had differed than the others. It showed a continuous decrease during the storage. Again, the HAF treatment was found to be effective. The fruits which were treated with HAF had higher TA values than the others.

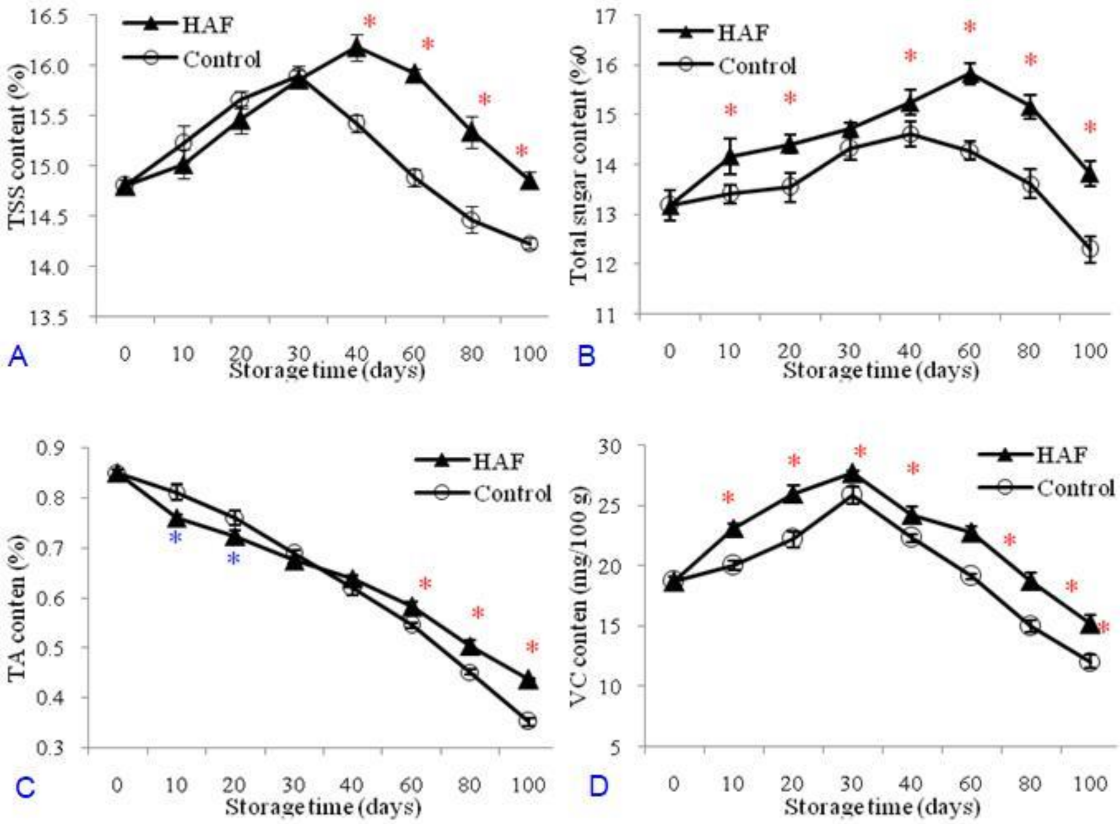

Figure 2. Effects of HAF on the contents of TSS (A), total sugar (B), TA (C) and VC (D) of Nanfeng mandarin during 100 days of cold storage at 6 °C. The symbol * and * (the HAF-treated fruit) represented significantly higher and lower than the control fruit, respectively. The significant difference was determined according to the independent samples t-test (P < 0.05) on each storage day.

Relationship between HAF and physiological quality parameters of Nanfeng mandarins

Mandarin fruits are non-climacteric fruits and do not ripen off-tree. Therefore, they only produce basal concentrations of ethylene and their respiration rate decreases during storage (Figure 3.). However, after a certain point, especially after physiological deterioration, the respiration rate generally increases. Thus, respiration rate is an important quality parameter for the both climacteric and non-climacteric fruits. In this experiment, the respiration rate of the Nanfeng mandarins was found to decrease during storage, until the 60th day of storage, and then it increased. It was also seen that HAF treated fruits had lower respiration rate as compared with the un-treated fruits.

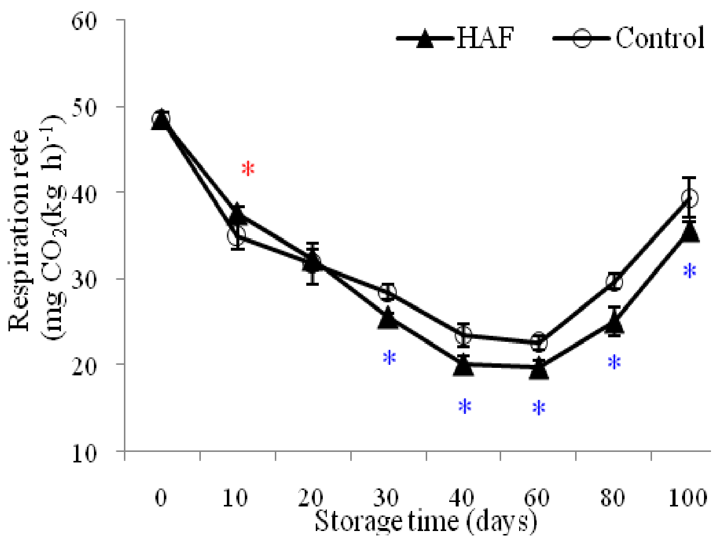

Figure 3. Effect of HAF on respiration rate of Nanfeng mandarin during 100 days of cold storage at 6 °C. The symbol * and * (the HAF-treated fruit) represented significantly lower than the control fruit. The significant difference was determined according to the independent samples t-test (P < 0.05) on each storage day.

Relationship between HAF and enzyme activity of Nanfeng mandarins

Malondialdehyde (MDA) is the end product of the lipid peroxidation (oxidative degradation of lipids) and is the sign of bio-chemical degradation. In line with information, it was observed that the MDA content increased during storage, while the HAF treated fruits had significantly lower MDA content as compared with the un-treated fruits (Figure 4.). As a support of this finding, it was then observed that the POD and SOD enzymes of the HAF treated fruits are higher than the un-treated fruits. These enzymes are known to alleviate lipid peroxidation (Sels et al., 2008). According to the obtained findings, the enzymatic activity of SOD and POD had an upward trend during the initial days of storage (around 40 days); and then they reduced. The final values of both SOD and POD were found to be higher than the initial values, where the HAF treated fruits' enzymatic activities were all higher than the un-treated fruits.

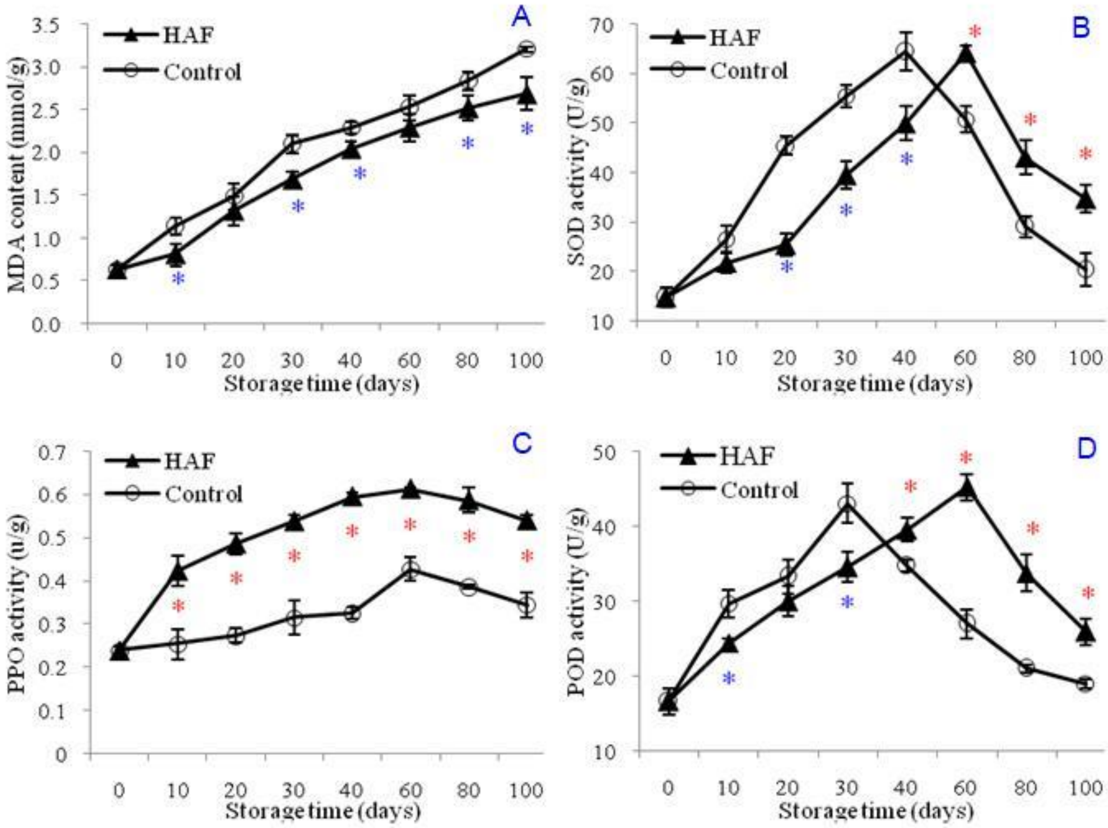

Figure 4. Effects of HAF on MDA content (A) and antioxidants enzyme (SOD, PPO and POD) activities of Nanfeng mandarin during 100 days of cold storage at 6 °C. The symbol * and * (the HAF-treated fruit) represented significantly higher and lower than the control fruit, respectively. The significant difference was determined according to the independent samples t-test ($P < 0.05$) on each storage day.

Among the tested enzymes, most significant effect was noticed on PPO enzyme. This is among the most important enzymes which is responsible from the disease resistance (Gao et al., 2018). It is clear from the results that PPO activity of the HAF treated fruits was doubled. This result supports the other findings of present study, where the HAF treated fruits had very less fungal decay. After 60 days of storage, the PPO activity of the HAF treated fruits had a slight reduction, but it was still higher than the initial values and un-treated fruits.

DISCUSSIONS

Results of present study support the main findings of some published literature (Erkan et al., 2005; Belovic et al., 2015; Wei et al., 2018; Wan et al., 2020) which suggested that hot ait treatment provide moderate to high efficacy in improving postharvest storability of fruits and vegetables. In a very similar study, Wan et al. (2020) reported that the HAF treatment is effective in protecting the physical, bio-chemical and physiological quality of Navel oranges. Wang et al. (2010) in their studies had found that HAF treatment is effective for controlling postharvest pathogens. In this study, the HAF treatment had also been effective for the prevention of the loss of bio-chemical quality parameters, such as: TSS, total sugar, VC and TA. Similarly, Erkan et al. (2005) noted that hot air treatment causes an increase in TSS and VC. Moreover, a study by Shen et al. (2012) recommended that hot air treatment preserves both the TSS and TA of Satsuma mandarins. In another very similar research, Gao et al. (2018b) reported that the hot air flow at 40 °C for 48 h provides favourable conditions for keeping the acidity of Ponkan fruits, as similar to the findings of present study.

Respiration rate is an important physiological parameter for the determination of the storage quality and storability. Reducing the respiration rate is known to increase storability of the fresh fruits. There are several studies which support our findings about the respiration rate. Similar to our results, Opio et al. (2017) and Wan et al. (2020) reported that hot air treatment reduces the respiration rate of citrus fruits. Besides to respiration rate, the MDA content of the HAF treated fruits decreased during storage, and this result is also in accordance with the findings of Wan et al. (2020). As indicated above, our results showed that HAF treatment is effective in increasing the enzymatic activity of POD, SOD and PPO. Current knowledge supports our findings where the activity of these enzymes had been associated with the prevention of lipid peroxidation and disease resistance (Sels et al., 2008; Gao et al., 2018). Yun et al. (2013) reported that HAF treatment increases the activities of SOD and POD at citrus fruits and is associated with the disease resistance. This result support our findings.

CONCLUSIONS

Current study made it possible to conclude that HAF treatment at 37 ºC for 36 h provides significant improvements in the enzymatic activity of SOD, POD and PPO at Nanfeng mandarins and reduce the respiration rate of the fruits during storage. These improvements in the physiological activity is then associated with the preservation of some bio-chemical quality parameters (TSS, TA, VC and total sugar) and physical quality parameter (weight loss). The improvements in the enzymatic activity and bio-chemical quality were also supported with the resistance against fruit decay. So, the overall results suggested that the HAF treatment is an effective tool for the preservation of the postharvest quality of Nanfeng mandarins.

FUNDING

This research was funded by Natural Science Foundation in Jiangxi Province (20171BAB214031), and Modern Agricultural Technology System of Citrus Industry (NOs. JXGS-05, and JXARS-07).

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Alvindia, D. G., & Acda, M. A. (2015). Revisiting the efficacy of hot water treatment in managing anthracnose and stem-end rot diseases of mango cv.'Carabao'. Crop Protection, 67, 96-101.

Atrash, S., Ramezanian, A., Rahemi, M., Ghalamfarsa, R. M., & Yahia, E. (2018). Antifungal effects of savory essential oil, gum arabic, and hot water in Mexican lime fruits. HortScience, 53(4), 524-530.

Ballester, A. R., Lafuente, M. T., & González-Candelas, L. (2006). Spatial study of antioxidant enzymes, peroxidase and phenylalanine ammonia-lyase in the citrus fruit–Penicillium digitatum interaction. Postharvest Biology and Technology, 39(2), 115-124.

Belović, M., Kevrešan, Ž., Pestorić, M., & Mastilović, J. (2015). The influence of hot air treatment and UV irradiation on the quality of two tomato varieties after storage. Food Packaging and Shelf Life, 5, 63-67.

Chen, J., Shen, Y., Chen, C., & Wan, C. (2019). Inhibition of key citrus postharvest fungal strains by plant extracts in vitro and in vivo: a review. Plants, 8(2), 26.

Connor, A. M., Luby, J. J., Hancock, J. F., Berkheimer, S., & Hanson, E. J. (2002). Changes in fruit antioxidant activity among blueberry cultivars during cold-temperature storage. Journal of agricultural and food chemistry, 50(4), 893-898.

Erkan, M., Pekmezci, M., Karasahin, I., & Uslu, H. (2005). Reducing Chilling Injury and Decay in StoredClementine'Mandarins with Hot Water and Curing Treatments. European Journal of Horticultural Science, 70(4), 183.

Feliziani, E., & Romanazzi, G. (2013). Preharvest application of synthetic fungicides and alternative treatments to control postharvest decay of fruit. Stewart Postharvest Review, 9(3), 1-6.

Gao, Y., Kan, C., Wan, C., Chen, C., Chen, M., & Chen, J. (2018). Quality and biochemical changes of navel orange fruits during storage as affected by cinnamaldehyde-chitosan coating. Scientia Horticulturae, 239, 80-86.

Gao, Y., Kan, C., Wan, C., Chen, C., Chen, M., & Chen, J. (2018a). Effects of hot air treatment and chitosan coating on citric acid metabolism in ponkan fruit during cold storage. PloS one, 13(11), e0206585.

Gao, J., Kahramanoğlu, İ., Usanmaz, S., Okatan, V., & Wan, C. (2021). The synergism effect of Scolymus maculatus L. plant extracts and hot water dipping on the postharvest storability of Valencia oranges. Pak. J. Bot., 53(6)

Henriod, R. E. (2006). Postharvest characteristics of navel oranges following high humidity and low temperature storage and transport. Postharvest biology and technology, 42(1), 57-64.

Hodges, D. M., DeLong, J. M., Forney, C. F., & Prange, R. K. (1999). Improving the thiobarbituric acid-reactive-substances assay for estimating lipid peroxidation in plant tissues containing anthocyanin and other interfering compounds. Planta, 207(4), 604-611.

Huan, C., Han, S., Jiang, L., An, X., Yu, M., Xu, Y., ... & Yu, Z. (2017). Postharvest hot air and hot water treatments affect the antioxidant system in peach fruit during refrigerated storage. Postharvest Biology and Technology, 126, 1-14.

Kader, A. A., & Arpaia, M. L. (1992). Postharvest handling systems: subtropical fruits. In: Kader, A.A. (Ed.), Postharvest Technology of Horticultural Crops; Third edition, publication number 3311. Regents of the University of California, Division of Agricultural and Natural Resources, Oakland, 375-384.

Kahramanoğlu, İ., & Usanmaz, S. (2019). Improving postharvest storage quality of cucumber fruit by modified atmosphere packaging and biomaterials. HortScience, 54(11), 2005-2014.

Kahramanoğlu, İ., Chen, C., Chen, Y., Chen, J., Gan, Z., & Wan, C. (2020a). Improving storability of "nanfeng" mandarins by treating with postharvest hot water dipping. Journal of Food Quality, 2020.

Kahramanoğlu, İ., Usanmaz, S., Alas, T., Okatan, V., & Wan, C. (2020b). Combined effect of hot water dipping and Cistus creticus L. leaf extracts on the storage quality of fresh Valencia oranges. Folia Horticulturae, 32(2), 337-350.

Kinay, P., Mansour, M. F., Gabler, F. M., Margosan, D. A., & Smilanick, J. L. (2007). Characterization of fungicide-resistant isolates of Penicillium digitatum collected in California. Crop Protection, 26(4), 647-656.

Opio, P., Jitareerat, P., Pongprasert, N., Wongs-Aree, C., Suzuki, Y., & Srilaong, V. (2017). Efficacy of hot water immersion on lime (Citrus auranifolia, Swingle cv. Paan) fruit packed with ethanol vapor in delaying chlorophyll catabolism. Scientia Horticulturae, 224, 258-264.

Sdiri, S., Salvador, A., Farhat, I., Navarro, P., & Besada, C. (2014). Influence of postharvest handling on antioxidant compounds of Citrus fruits. Citrus: molecular phylogeny, antioxidant properties and medicinal uses, 73-94.

Sels, J., Mathys, J., De Coninck, B. M., Cammue, B. P., & De Bolle, M. F. (2008). Plant pathogenesis-related (PR) proteins: a focus on PR peptides. Plant Physiology and Biochemistry, 46(11), 941-950.

Shen, Y., Zhong, L., Sun, Y., Chen, J., Liu, D., & Ye, X. (2013). Influence of hot water dip on fruit quality, phenolic compounds and antioxidant capacity of Satsuma mandarin during storage. Food science and technology international, 19(6), 511-521.

Suleria, H. A. R., Butt, M. S., Anjum, F. M., Saeed, F., & Khalid, N. (2015). Onion: Nature protection against physiological threats. Critical reviews in food science and nutrition, 55(1), 50-66.

Wan, C., Kahramanoğlu, İ., Chen, J., Gan, Z., & Chen, C. (2020). Effects of hot air treatments on postharvest storage of Newhall navel orange. Plants, 9(2), 170.

Wan, C., Kahramanoğlu, İ., & Okatan, V. (2021). Application of plant natural products for the management of postharvest diseases in fruits. Folia Horticulturae, 33(1), 1-13.

Wang, C. Y. (2004, September). Alleviation of chilling injury in tropical and subtropical fruits. In III International Symposium on Tropical and Subtropical Fruits 864 (pp. 267-273).

Wang, L., Jin, P., Wang, J., Gong, H., Zhang, S., & Zheng, Y. (2015). Hot air treatment induces resistance against blue mold decay caused by Penicillium expansum in sweet cherry (Prunus cerasus L.) fruit. Scientia Horticulturae, 189, 74-80.

Wei, Y., Wei, Y., Xu, F., & Shao, X. (2018). The combined effects of tea tree oil and hot air treatment on the quality and sensory characteristics and decay of strawberry. Postharvest Biology and Technology, 136, 139-144.

Yun, Z., Gao, H., Liu, P., Liu, S., Luo, T., Jin, S., ... & Deng, X. (2013). Comparative proteomic and metabolomic profiling of citrus fruit with enhancement of disease resistance by postharvest heat treatment. BMC Plant Biology, 13(1), 1-16.

Zhang, M., Liu, W., Li, C., Shao, T., Jiang, X., Zhao, H., & Ai, W. (2019). Postharvest hot water dipping and hot water forced convection treatments alleviate chilling injury for zucchini fruit during cold storage. Scientia Horticulturae, 249, 219-227.