International Journal on Food, Agriculture, and Natural Resources
Volume 05, Issue 04, Page 17-21
ISSN: 2722-4066
http://www.fanres.org

Original Paper

Effect of Steam Treatment on The Shelf Life of Tomato (*Solanum Lycopersicum* L.) Fruits

*Balogun Olalekan Topsy**, Aborisade A.T., Akomolafe O.M.*
Department of Biology, The Federal University of Technology, PMB 704 Akure Ondo State, Nigeria.
*) *Corresponding Author: balogunbio153887ha@futa.edu.ng*

Received: 19 July 2024; Revised: 26 September 2024; Accepted: 06 December 2024
DOI: *https://doi.org/10.46676/ij-fanres.v5i4.375*

***Abstract*— The effect of heating harvested fruits before storage varies depending on factors such as the fruit cultivar, heating method, and storage conditions. In this research, tomato fruits at different maturity stages were treated with steam and then stored at 28°C. Mature-green stage fruits heated at 55°C for 10 and 30 minutes showed no signs of rot for 24 days. Breaker-stage fruits heated at 55°C for 10 and 20 minutes, as well as at 60°C for 10 minutes, remained disease-free during storage. Heating at 55°C for 30 minutes enhanced the colour development of mature-green fruits, and the same effect was observed for breaker-stage fruits heated at 55°C and 60°C for 20 minutes. However, steam treatment did not effectively protect red-ripe fruits, as they decayed faster than the control group. Significant heat injury was observed only in breaker stage fruits heated for 20 and 30 minutes at 55°C, and 10 and 30 minutes at 60°C. The fungi causing decay isolated from diseased fruits were Fusarium oxysporum, Colletotrichum gloeosporioides, Rhizopus stolonifer, Geotrichum candidum, and Aspergillus niger.**

Keywords*— *Steam Treatment, Tomato Fruits, Shelf-life, Harvesting Stage, Fruits Decay.

I. INTRODUCTION

Heat treatment is generally used to achieve pre-storage insect and microbial control on harvested plant commodities since it offers effective non-chemical protection [1][2][3][4]. Shelf-life extension is usually the resultant effect as the insects are not able to feed on the commodity preventing the formation of ports of entry through which other organisms may penetrate. While concerns have been raised over chemical methods of post-harvest fruit disinfection due to the residual byproducts, research has shown the potential of heat treatment as a promising and safer post-harvest treatment for fruits and vegetables [5][3]. Heat application has a direct effect on bacteria and fungi through cell and spore inactivation. This as a result delays or prevents fruit rot, controls insect pests, slow ripening and increases tolerance to chilling injury [6][7]. Heat also elicits the production of antifungal chemical compounds which act in synergism with cell inactivation or spore kill effect, making it more efficient in plant protection. Although the various forms of heat treatment, particularly at extreme temperatures may result in physiological injuries such as scalding or a 'boiled' effect [8], fruit changes such as reduced firmness due to the activity of pectinmethylesterase [9], colour change resulting from inhibition of lycopene accumulation and chlorophyll degradation [10][11], respiratory metabolism and chemical composition changes [10][12], and change in ethylene production [13]. Further, heat treatment affects physiological processes such as ripening, water loss and ion transport [14][15] within tissues of the plant. It may also affect the response of the plant to stresses such as temperature and pH fluctuations as is observed in chilling injury response when the plant commodity is stored at refrigeration temperature afterwards [16]. This is in addition to the effect on nutrient status and physicochemical characteristics including total soluble solids, acidity, and pH [8][17]. The advantage of heat treatment is that it can be used instead of preservative chemicals which may have adverse effects on the health of the consumer despite the relative ease of application. Sometimes, however, heat is used in combination with fungicides as brief hot dips or drenches to enhance the effectiveness of the chemicals. For protection, it is necessary to prevent recontamination after heat treatment.

Steam, also referred to as vapour heat, has higher penetrating power than hot air but has the disadvantage of wetting produce which could promote the growth of surviving microbes. Tomato fruits at different stages of ripening have been subjected to single and double regimes [18] of hot water/ steam/hot air treatments before storage with contradicting reports on their efficacy in extending storage life. The responses of the fruits were reported to vary with the cultivar, stage of ripening and the temperature-time protocol employed. Mature green and pink tomatoes that were steam treated to 38°C core temperature were not affected in colour development [14]. Steam, also applied on mature-green tomato fruits at 45°C for 1 minute produced significant disease control within a 5-day ambient storage period after inoculation with Fusarium verticillioides just below the surface and those deep inoculated at 10mm [19]. Breaker fruits inoculated at 1mm depth were similarly protected by 5 minutes of exposure. Steam is hereby being tested alone at 55°C and 60°C for 10, 20 and 30 minutes on mature-green, breaker and red-ripe tomato fruits to determine the effect on shelf life and ripening characteristics of treated

fruits which remain healthy for significant lengths of time post-treatment. The temperatures being presently investigated have been tested on oranges [20] and vapour heat at 50°C was tested on mature-green and breaker Roma tomato fruits [21].

II. Materials And Methods

A. Treatment

Healthy, unbruised, mature-green, breaker and red-ripe tomato fruits were separately exposed to steam in a Gallenkamp water bath after surface disinfection in 0.385%w/v sodium hypochlorite for 10 minutes. The temperatures tested were 55°C and 60°C for 10, 20 and 30 minutes.

B. Storage

The fruits were then individually placed on sterile Petri plates, kept in disinfected plastic boxes with close-fitting lids and placed on a laboratory side bench at 28°±2°C. Mature green and breaker fruits were visually observed for colour development at three-day intervals for 24 days [22].

C. Quality Assessment

The extent of ripening was rated on a scale of 1 – 5 as 1=mature green; 2=breaker (green, tarnish yellow, red colour not more than 10% surface area); 3=turning (orange to red colouration greater than 10% but not more than 30% aggregate surface area); 4=pink (orange to red colouration greater than 30% but not more than 60% surface area); 5= light red (red colouration greater than 60% but not more than 90% surface area); 6=red ripe (red colouration greater than 90% surface area) according to Anon et al [22]. Ripening rating was done for mature-green and breaker-stage fruits only.

III. Results And Discussion

A. Soil Physical Characteristics

Applying steam treatment resulted in increased colour development in mature green fruits compared to the control group. By the 24th day of storage, the control fruits were still between the pink and light-red stages, while all heat-treated fruits had reached the maximum red colour (Figure 1). The difference in fruit response was noticeable from day 9. Most steam-treated mature-green fruits had progressed beyond the pink ripening stage by day 9, except those treated at 55°C for 10 minutes and 60°C for 20 minutes, which were still between the turning and pink stages. The ripening of steam-treated breaker fruits was also generally enhanced, as observed on day 9, except those treated at 60°C for 30 minutes. These fruits were severely inhibited compared to the control but reached the pink stage by day 21 and the light-red stage on day 24, showing no significant difference from all other treatments, including the control (Figure 2).

During the study, it was observed that the mature-green and red-ripe fruits did not show significant heat injury as a result of steam treatment at both temperatures, in comparison to the breakers which exhibited significant heat injury when exposed to 60°C for longer periods (Table 1). The occurrence of disease on the fruits was irrespective of the treatment applied. The fungi associated with the decays included *Fusarium oxysporum*, *Geotrichum candidum*, *Aspergillus niger*, *Colletotrichum gloeosporioides*, and *Rhizopus stolonifer*.

In the case of mature green fruits, it was found that treatment at 55°C for 10 and 30 minutes did not lead to rot development throughout the 24-day storage period. Conversely, rot development was most severe on fruits treated at 60°C for 20 and 30 minutes (Table 2).

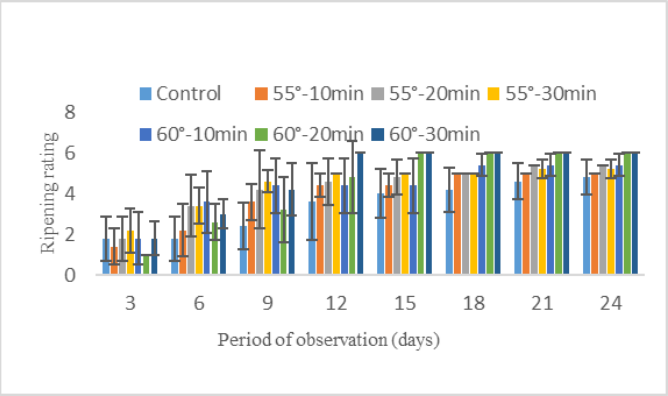

Fig. 1. Ripening rating of mature-green tomato fruits exposed to pre-storage steam treatment

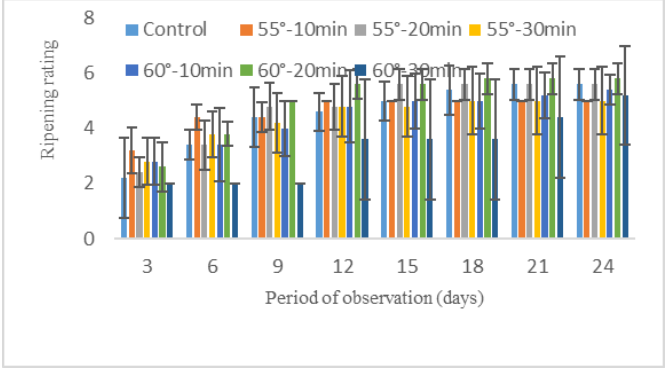

Fig. 2. Ripening rating of breaker tomato fruits exposed to pre-storage steam treatment

TABLE I. HEAT INJURY ON TOMATO FRUITS EXPOSED TO STEAM AT 55° AND 60°C

Treatment	Stage of maturity/Heat Injury rating		
	Mature-green	Breaker	Red-ripe
Control	1.00±0.00[a]	1.00±0.00[a]	1.00±0.00[a]
55° - 10min	1.00±0.00[a]	1.00±0.00[a]	1.00±0.00[a]
55° - 20 min	1.00±0.00[a]	1.60±0.40[b]	1.00±0.00[a]
55° - 30 min	1.00±0.00[a]	1.40±0.24[b]	1.00±0.00[a]
60° - 10 min	1.20±0.20[a]	1.60±0.40[b]	1.20±0.20[a]
60° - 20 min	2.00±0.32[a]	2.40±0.44[c]	1.20±0.20[a]
60° - 30 min	1.80±0.58[a]	3.40±0.00[c]	1.20±0.20[a]

Values are means of three replicates ± SE of the means. Values followed by the same alphabet in a column are not significantly different by Tukey test at α=0.05

The disease was more severe on breaker fruits treated at 60°C for 20 and 30 minutes while those heated for 10 minutes remained disease-free for 24 days (Table 3). The control red-ripe fruits showed less disease development compared to the heated fruits. Red-ripe fruits treated at 60°C for 20-30 minutes decayed rapidly during storage (Table 4)

TABLE II. DISEASE SEVERITY RATING ON MATURE GREEN TOMATO FRUITS EXPOSED TO STEAM AND STORED AT 28°±2°C

	Storage Period (Days)/ Disease rating							
Treatment	3	6	9	12	15	18	21	24
Control	1.0±0.00^{a}	1.4±0.55^{a}	1.60±0.89^{a}	1.80±0.83^{a}	1.80±0.84^{a}	2.20±1.30^{a}	2.40±1.67^{a}	2.40±1.67^{a}
55°-10min	1.0±0.00^{a}	1.0±0.00^{a}	1.0±0.00^{a}	1.0±0.00^{a}	1.0±0.00^{a}	1.00±0.00^{a}	1.0±0.00^{a}	1.00±0.00^{a}
55°-20min	1.0±0.00^{a}	1.20±0.45^{a}	1.20±0.45^{a}	1.20±0.45^{a}	1.20±0.45^{a}	1.20±0.45^{a}	1.20±0.45^{a}	1.20±0.45^{a}
55°-30min	1.0±0.00^{a}	1.0±0.00^{a}	1.0±0.00^{a}	1.0±0.00a	1.0±0.00^{a}	1.00±0.00^{a}	1.00±0.00^{a}	1.00±0.00^{a}
60°-10min	1.0±0.00^{a}	1.60±0.89^{a}	1.80±1.30^{a}	1.80±1.30^{a}	2.00±1.73^{a}	2.00±1.73^{a}	2.00±1.73^{a}	2.00±1.73^{a}
60°-20min	1.40±0.89^{a}	3.40±0.89^{b}	4.60±0.54^{b}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}
60°-30min	1.20±0.44^{a}	3.60±1.67^{a}	5.0±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}

VALUES ARE MEANS OF FIVE REPLICATES ± STANDARD ERROR (SE) OF THE MEAN. MEANS FOLLOWED BY THE SAME LETTER IN A COLUMN ARE NOT SIGNIFICANTLY DIFFERENT BY TUKEY

TABLE III. DISEASE SEVERITY RATING ON BREAKER TOMATO FRUITS EXPOSED TO STEAM AND STORED AT 28°±2°C

	Storage Period (Days)/ Disease rating							
Treatment	3	6	9	12	15	18	21	24
Control	1.20±0.45^{a}	1.20±0.45^{b}	1.20±0.45 ^{a}	1.20±0.45 ^{a}	1.20±0.45 ^{a}	1.20±0.45 ^{a}	1.20±0.45^{a}	1.20±0.45 ^{a}
55°-10min	1.00±0.00 ^{a}	1.00±0.00 ^{a}	1.00±0.00 ^{a}	1.00±0.00 ^{a}	1.00±0.00 ^{a}	1.00±0.00 ^{a}	1.00±0.00 ^{a}	1.00±0.00 ^{a}
55°-20min	1.00±0.00 ^{a}	1.00±0.00 ^{a}	1.00±0.00 ^{a}	1.00±0.00 ^{a}	1.00±0.00 ^{a}	1.00±0.00 ^{a}	1.00±0.00 ^{a}	1.00±0.00 ^{a}
55°-30min	1.00±0.00 ^{a}	1.00±0.00 ^{a}	1.20±0.45 ^{a}	1.20±0.45 ^{a}	1.60±0.89 ^{a}	2.00±1.73^{b}	2.00±1.73 ^{a}	2.00±1.73 ^{a}
60°-10min	1.00±0.00 ^{a}	1.00±0.00 ^{a}	1.0±0.00 ^{a}	1.00±0.00 ^{a}	1.00±0.00 ^{a}	1.00±0.00 ^{a}	1.00±0.00^{a}	1.00±0.00 ^{a}
60°-20min	1.40±0.55 ^{a}	2.60±0.89^{b}	2.80±1.09^{b}	3.40±1.15^{b}	3.40±1.15^{b}	4.40±1.34^{b}	4.40±1.34^{b}	4.40±1.34^{b}
60°-30min	1.20±0.45 ^{a}	2.20±1.60^{b}	2.60±1.14^{b}	3.00±2.04^{b}	3.20±2.04^{b}	4.40±1.34^{b}	4.40±1.34^{b}	4.40±1.34^{b}

VALUES ARE MEANS OF FIVE REPLICATES ± STANDARD ERROR (SE) OF THE MEAN. MEANS FOLLOWED BY THE SAME LETTER IN A COLUMN ARE NOT SIGNIFICANTLY DIFFERENT BY TUKEY TEST AT A=0.05

TABLE IV. DISEASE SEVERITY RATING ON RED-RIPE TOMATO FRUITS EXPOSED TO STEAM AND STORED AT 28°±2°C

	Storage Period (Days)/ Disease rating							
Treatment	3	6	9	12	15	18	21	24
Control	1.20±0.45^{a}	1.40±0.55 ^{a}	1.40±0.55 ^{a}	1.40±0.54 ^{a}	1.40±0.55 ^{a}	1.40±0.55 ^{a}	1.40±0.55 ^{a}	2.00±1.73 ^{a}
55°-10min	1.20±0.45 ^{a}	1.60±0.89 ^{a}	1.60±0.89 ^{a}	2.00±1.73 ^{a}	2.20±1.64 ^{a}	2.20±1.64 ^{a}	2.20±1.64 ^{a}	2.80±1.30 ^{a}
55°-20min	1.00±0.00 ^{a}	2.40±1.67^{b}	2.60±1.81^{b}	2.80±2.04 ^{a}	2.80±2.04 ^{a}	2.80±2.04 ^{a}	2.80±2.04 ^{a}	2.80±2.04 ^{a}
55°-30min	1.20±0.45 ^{a}	1.80±0.83 ^{a}	2.80±1.22 ^{a}	2.20±1.64 ^{a}	2.20±1.64 ^{a}	2.20±1.64 ^{a}	2.40±1.64 ^{a}	2.40±1.51 ^{a}
60°-10min	1.00±0.00 ^{a}	2.60±1.52^{b}	4.20±0.84^{c}	4.80±0.45^{b}	5.00±0.00^{c}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}
60°-20min	1.00±0.00 ^{a}	4.00±0.70^{c}	5.00±0.00^{c}	5.00±0.00^{b}	5.00±0.00^{c}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}
60°-30min	1.00±0.00 ^{a}	5.00±0.00^{c}	5.00±0.00^{c}	5.00±0.00^{b}	5.00±0.00^{c}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}

Values are means of five replicates ± standard error (SE) of the mean. Means followed by the same letter in a column are not significantly different by Tukey test at α=0.05

IV. DISCUSSION

The results of our study show that heating fruits at the mature-green and breaker stages at 55°C and 60°C enhances colour development and promotes ripening without causing heat injury. This is consistent with previous studies which found that mature green tomato fruits exposed to hot air at 60°C ripened beyond the turning stage by the 10th day, meanwhile, steam being more efficient than hot air, caused faster ripening [23][24]. Lurie and Sabehat, [25] and McDonald et al. [26] similarly reported the impact of heat treatments on the colour development of mature green tomatoes. The later author specifically found that red colour development in mature-green "Sunbeam" tomato fruits were promoted by hot air and hot water treatment at 38oC and 48°C for various hours respectively. This is consistent with Aborisade and Iyun [23] finding that heat treatment inhibits ripening processes in mature green and pink tomatoes during heating at 38°C for three days. However, their treated fruits later attained a uniform red colour. These findings are in congruence with earlier research such as Sabehat [27] who found the significance of hot water treatment at 45oC for 10 minutes in mature-green tomato pericarp discs, Pinheiro et al.,[28] observed similar changes in mature green tomatoes heated at 40-60oC for several minutes in hot water, Yahia et al.,[29] findings on mature green tomato at 40 or 45oC for 5 or 15 minutes in hot water, while a reduced temperature using hot air at 34oC for a longer time (24hrs) was also reported to bring about this changes in cherry tomato [4]. Our finding is in line with these previous authors' claims, as our finding demonstrated that various heat treatments resulted in colour development in tomato fruits, especially those at the mature-green stages. The higher colour rating observed by day 12 on all steam-treated breaker fruits except those exposed to 60°C for 30 minutes in our research proves this enhanced ripening effect. Heat injury on breaker fruits exposed for 30 minutes at 60°C was perhaps because of retarded ripening of those fruits, although they still ripened to the pink stage by day 21.

The study observed that mature-green stage fruits exposed to 55°C for 10 and 30 minutes, as well as breaker stage fruits heated at 55°C for 10 and 20 minutes followed by 60°C for 10 minutes, showed protection from fungal attack. This protection is likely due to a combination of natural protective compounds in the fruit and the destruction of microbes by heat. Steam treatment at these temperatures and durations is recommended for mature green and breaker-stage tomatoes. However, red-ripe fruits showed more severe rot after treatment, indicating that steam treatment at 55°C and 60°C did not benefit this maturity stage. The severe rot on breaker-stage fruits exposed to 60°C for a longer period was caused by significant heat injury, which damaged the fruit tissue. Additionally, heat enhancement of softness (total soluble solid) and sugar content (titratable acidity) of red-ripe fruits accelerated their decay after treatment. This heat injury compromised the fruit's membrane integrity, making it more vulnerable to fungal attack and rot development.

In this study, some fungi associated with tomato fruits have also been reported by other authors. For example, Fajola [30] reported that Rhizopus stolonifer and Fusarium oxysporum are soft rot pathogens on tomato fruits in Nigeria. The fact that these fungi were found on diseased fruits in our study, regardless of treatment, confirms that they specifically target tomato fruits, although they can also cause decay in other fruits. We observed that the shelf life of tomato fruits can be extended for up to 24 days under ambient storage conditions. Previous reports of shelf-life extension through heat treatment only resulted in shorter periods, even when low-temperature storage was used after heat treatment [18][19][31][32]. The two heating temperatures we used are suitable for extending shelf life and maintaining quality at all three maturity stages we studied, although the optimal treatment time varies depending on the stage.

V. Conclusions

Treating tomato fruits (mature green and breakers) with steam heat at 55°C and 60°C, and then storing them at room temperature, enhances color development. Once activated, the ripening factor continues to increase, regardless of the heat treatment. This enhanced colour development is more significant in mature green tomato fruits. However, exposing breaker tomato fruits to steam heat at 60°C for 30 minutes causes significant heat injury. Despite the heat injury, ripening progresses to the pink stage by day 21. Treating mature green tomatoes with steam heat at 55°C for 10 and 30 minutes, and treating breaker fruits at 55°C for 10 and 20 minutes followed by 60°C for 10 minutes, protects against decay and microbial attack, particularly fungal attack. However, 55°C and 60°C steam treatments do not protect red-ripe tomato fruits from decay. Nonetheless, physiological improvement is noted. Fungi associated with fruit decay include Fusarium oxysporum, Colletotrichum gloeosporioides, Rhizopus stolonifer, Geotrichum candidum, and Aspergillus niger. This study reports that shelf-life extension for tomato fruits following steam treatments, and when stored at room temperature, can be as long as 24 days.

Acknowledgments

We acknowledge the Department of Biology, Federal University of Technology, Akure Ondo State Nigeria, and the laboratory technicians during the cause of the experiment.

References

[1] Lu, J., Vigneault, C., Charles, M.T., Raghavan, G.S.V., 2007. Heat treatment application to increase fruit and vegetable quality. Stewart Postharvest Review 3, 41–47.

[2] Lu, J., Vigneault, C., Charles, M.T., Raghavan, G.S.V., 2010. Effect of heat treatment uniformity on tomato ripening and chilling injury. Postharvest Biology and Technology 56 (2010) 155–162.

[3] Joaquina Pinheiro, Carla Alegria, Marta Abreu , Manuela Sol , Elsa M. Gonçalves and Cristina L.M. Silva, (2015). Postharvest Quality Of Refrigerated Tomato Fruit (Solanum Lycopersicum, Cv. Zinac) At Two Maturity Stages Following Heat Treatment. Journal of Food Processing and Preservation. doi:10.1111/jfpp.12279.

[4] Soto-Zamora, G., Yahia, E.M., Brecht, J.K., Gardea, A., 2005. Effects of postharvest hot air treatments on the quality and antioxidant levels in tomato fruit. LWT: Food Science and Technology 38 (6), 657–663.

[5] Boukobza, F. And Taylor, A.J. 2002. Effect of postharvest treatment on flavour volatiles of tomatoes. Postharvest Biol. Technol. 25, 321–331.

[6] McDonald, R.E.; McCollum,T. G. and Baldwin, E.A. (1995). Heat treatments extend the shelf-life of tomato fruit. HortScience 30(4): Doi:10.21273/HORTSCI.30.4.786D

[7] Aborisade, A.T. and Ojo, F.H. (2002). Effect of .postharvest hot air treatment of tomatoes (Lycopersicon esculentum Mill) on storage life and decay caused by Rhizopus stolonifer. Journal of Plant Diseases and Protection 109(6):639-645.

[8] Jacobi, K.K and Giles, J.E. (1997). Quality of 'Kensington' mango (Mangifera indica Linn.) fruit following combined vapour heat disinfestations and hot water disease control treatments. Postharvest Biology and Technology 12:285-292.

[9] LURIE, S. 1998. Postharvest heat treatments-review. Postharvest Biol. Technol. 14, 257–269.

[10] KLEIN, J.D. and LURIE, S. 1992. Heat treatments for improved postharvest quality of horticultural crops. Horttechnology 2, 316–320.

[11] Iwahashi, Y. And Hosoda, H. (2000). Effect of heat stress on tomato fruit protein expression. Electrophoresis 21, 1766–1771.

[12] Lurie, S. And Klein, J.D. (1991). Acquisition of low temperature tolerance in tomatoes by exposure to high temperature stress. J. Am. Soc. Hortic. Sci. 116, 1007–1012

[13] Biggs, M.S., Woodson, W.R. And Handa, A.K. (1988). Biochemical basis of high temperature inhibition of ethylene biosynthesis in ripening tomato fruits. Plant Physi. 72, 572–578

[14] Fallik, E.; Klein, J.; Grinberg, S.; Lomaniec, E.; Lurie, S. and Lalazar, A. (1993). Effect of postharvest heat treatment of tomatoes on fruit ripening and decay caused by Botrytis cinerea. Plant Disease 77(10):985-988.

[15] Lurie, S.; Othman, S. and Borochov, A. (1995). Effects of heat treatment on plasma membrane of apple fruit. Postharvest Biology and Technology 5:29-38.

[16] Klein, J.D and Lurie, S. (1990). Prestorage heat treatment as a means of improving poststorage quality of apples. Journal of American Society for Horticultural Science 115(2):265-269.

[17] Whitaker, B.D. (1994). A reassessment of heat treatment as a means of reducing chilling injury in tomato fruit. Postharvest Biology and Technology 4:75-8.

[18] Aborisade, A.T and Akande, I.O (2014). Response of Roma tomatoes inoculated with Fusarium nivale to Hot air treatment. Nigerian J. Plant Protection 28:66-72.

[19] Aborisade, A.T and Adegoke, O.M (2009). Heat treatment reduces decay of tomato (Lycopersicon esculentum) fruits by Fusarium verticillioides. Nigerian J. Mycol. 2(1):90-97.

[20] Aborisade, A.T and Elufisan, O.O (2021): Extension of shelf life of Penicillium digitatum infected sweet oranges by vapour heat treatment. ActaHortic.1325:41-46.https://doi.org/10.17660/ActaHortic.2021.1327.7

[21] Onitekun, A.M.; Akomolafe, O.M. and Aborisade, A.T. (2012). Influence of post-harvest heat treatment of tomatoes on fruit ripening and decay caused by Fusarium verticillioides. Journal Res. Sci. Mgt. 8(1):1-6.

[22] Anon (1975). Ripening stages for tomatoes. The California Tomato Board. USDA Visual Aid.

[23] Aborisade, A.T (2011). Effect of pre-inoculation heating after harvest on ripening and resistance of tomato fruits to Rhizopus stolonifer infection during storage. Nigerian Journal of Plant Protection 25:55-62.

[24] Aborisade, A.T. and Iyun, O.J. (2007). Non inhibition of ripening in hot air treated tomato (Lycopersicon esculentum Mill) fruits. Journal of Plant Sciences 2(3):318-325.

[25] Lurie, S. And Sabehat, A. (1997). Prestorage temperature manipulations to reduce chilling injury in tomatoes. Postharvest Biol. Technol. 11, 57–62

[26] McDonald, R.E.; McCollum, T.G. and Baldwin, E.A. (1999). Temperature of water heat treatments influences tomato fruit quality following low-temperature storage. Postharvest Biology and Technology 16(2):147-155.

[27] Sabehat, A., Weiss, D., Lurie, S., (1996). The correlation between heat-shock protein accumulation and persistence and chilling tolerance in tomato fruit. Plant Physiol. 110, 531–537.

[28] Pinheiro, J., Silva, C.L.M., Alegria, C., Abreu, M., Sol, M. and Gonçalves, E.M. (2012). Impact of water heat treatment on physical-chemical, biochemical and microbiological quality of whole tomato (Solanum lycopersicum) fruit. Acta Horticulturae (ISHS) 934, 1269–1276. http://www.actahort.org/books/934/934_172.htm (accessed August 26, 2024)

[29] Yahia, E.M., Soto-Zamora, G., Brecht, J.K. And Gardea, A. (2007). Postharvest hot air treatment effects on the antioxidant system in stored mature-green tomatoes. Postharvest Biol. Technol. 44, 107–115

[30] Fajola, A.O. (1979). The post-harvest fruit rots of tomato (Lycopersicon esculentum) in Nigeria. Food Nahrung 23(2):105-109.

[31] Artes, F.; Sanchez, E. and Tijskens, L.M.M (1998). The quality and shelf-life of tomatoes improved by intermittent warming. LWT – Food Science and Technology 31(5):427-431.

[32] Aborisade, A.T; Ademosun, A.O and Babalola, A.I (2014). Resistance against Rhizopus stolonifer (Ehrenb.ex Link) by tomato fruits subjected to two regimes of heat treatment. Nigerian J Plant Protection 28:45-54.