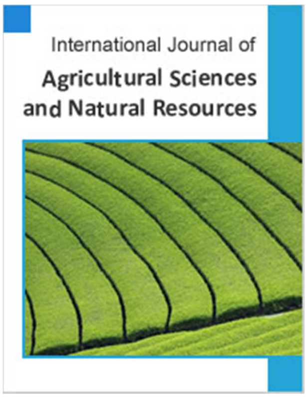
International Journal of Agricultural Sciences and Natural Resources
2017; 4(6): 43-49
http://www.aascit.org/journal/ijasnr
ISSN: 2375-3773

American Association for Science and Technology



Effect of Heat Treatment on Decay Caused by *Fusarium nivale* Fries. on Tomato

Adegoke Oluwatosin Aderonke[1, *], Aborisade Abiola Titilola[2]

[1]Department of Botany/Science, University of Ibadan, Nigeria
[2]Department of Biology/Science, Federal University of Technology, Akure, Nigeria

Email address

adegoketosinfam@gmail.com (A. O. Aderonke)
[*]Corresponding author

Keywords

Fusarium nivale, Heat Treatment, Ripening Stages, Storage Period, Disease Severity

Received: April 21, 2017
Accepted: November 1, 2017
Published: December 6, 2017

Citation

Adegoke Oluwatosin Aderonke, Aborisade Abiola Titilola. Effect of Heat Treatment on Decay Caused by *Fusarium nivale* Fries. on Tomato. *International Journal of Agricultural Sciences and Natural Resources.* Vol. 4, No. 6, 2017, pp. 43-49.

Abstract

Healthy matured tomato at various ripening stages (Mature-green, breaker, turning, pink, light-red and red-ripe) were surface inoculated with spores of *Fuarium nivale* and exposed to heat treatment using hot air at 46°C for 1 hour ($HA46^{1h}$), 70°C for 4 minutes ($HA70^{4}$), 70°C for 6 minutes ($HA70^{6}$) and hot water at 48°C for 10 minutes ($HW48^{10}$), and 42°C for 25 minutes ($HW42^{25}$). Control was similarly set up without treatment. The fruits were then stored in dessicators for at 28±2°C at 100% relative humidity. Disease severity was observed at 24hrs interval for 11days storage period. Results reveal that heat treatment reduced disease severity by *F. nivale* at all ripening stages within the storage period of 11days except $HA70^{6}$, $HW42^{25}$, $HA40^{1h}$ in mature-green fruits. Result also indicated $HA70^{4}$ and $HW48^{10}$ were most effective on mature-green and breaker tomato fruits, $HA70^{4}$ was most effective on turning and pink fruits, $HA70^{6}$ was the best for light-red and $HA70^{4}$ for red-ripe tomato fruits. However, the efficacy of treatment depends on the ripening stage of the fruit and the duration of preservation.

1. Introduction

Tomato is one of the most important vegetable crops in the world of horticulture. It contributes to a healthy and well balanced diet being a very good source of vitamin C, molybdemum, potassium, manganese and chromium [1].

In Nigeria, the major production occurs in the Northern part of the country and takes at least two days before it is made available to the retailers, thereby having a time lag of at least 3-4 days between harvest and purchase by the final consumer. Tomato fruits are mostly poorly handled and the fruit has to undergo various climatic conditions during transportation to other parts of the country before it reaches the retailer or consumer. Coupled with Nigeria's favorable climate to pest and diseases, majority of the tomato fruits may be infected with diseases before, duringor after harvest. As a result, the quality of the fruits reduces and spoilage occurs within a short time after harvest leading to loss of the produce.

Reduction of loss caused by pathogen can be achieved by good farm practices. However, chemical method of disease is commonly used by farmers. Fungicides are used extensively for postharvest disease control in fruits and vegetables. Postharvest fungicides can be applied as dips, sprays, fumigants, treated wraps and box liners or in waxes and coatings [2]. On the other hand, there is an increasing awareness of the potential dangers of some chemicals to health and the environment as well as an increasing demand for nonchemically treated produce by consumers.

There are various non chemical techniques to control diseases of postharvest fruits among which heat treatment appears to be one of the most effective [3], [4]. There are reports of various degrees on success of heat treatment like hot air, vapour heat, solar radiation, hot water dip or spray or in combination with other methods [5].

Heat treatment has been reported to control decay fungi *Botrytis cinerea* and *Rhizopuss tolonifer* in tomato [6], [7]. As yet, there is no such report on the effectiveness of such treatment on *Fusarium nivale* as pathogen of tomato, hence prompting this study to investigate the effect of heat treatment on the dacay causing fungus at all ripening stage through 11 days storage period.

2. Materials and Methods

2.1. Sample Source Collection and Preparation

The cultivar used was UTC tomatoes, harvested from Zaria and transported to the Biology Laboratory of the Federal University of Technology, Akure, Ondo State. Only mature fruits were used. Healthy unblemished fruits were sorted from the harvested tomatoes. Prior to grading, the tomatoes were washed in portable water and then graded as follows;

Stage 1-fully mature - green

Stage 2-breaker (green to tarnish yellow, traces of red not more than 10%surface area)

Stage 3-turning (orange to red, greater than 10% but not more than aggregate of 30%)

Stage 4-Pink (orange to red, greater than 30% aggregate but not more than 60% surface area)

Stage 5-Light red (greater than 60% red but not more than 90% surface area)

Stage 6-Red (greater than 90% surface area red) (The California Tomato Board, 1975)

The graded healthy tomatoes were rinsed in 0.385%m/v sodium hypoclorite solution for surface disinfection.

2.2. Preparation of Culture Medium

The culture medium used was Potato Sucrose Agar (PSA). Potato extract was prepared, by boiling 250g peeled and chopped potato in muslin cloth suspended in 1 litre of water for 30minutes. The potatoes were discarded leaving the fluid which is the potato extract. To 1 litre of the potato extract in a conical flask, 1 litre of water, 20g of sucrose and 20g of agar were added and autoclaved for 15 minutes at 121°C for sterilization. It was then allowed to cool, poured into sterile Petri-dishes and allowed to solidify.

2.3. Preparation of Inoculum

Conidia suspension used as inoculum for the experiment was prepared from a culture of *Fusarium nivale* on potato sucrose medium in agar. It was transferred with the medium into 200ml of sterile water in conical flask and shaken for a few minutes to dislodge the conidia. The suspension formed was then filtered using sterile cotton wool. The filtrate was collected in a sterile beaker. To quantify the number of spores, the method of [8] was used following the equation:

Number of spore ml^{-1} = Average number of sporesx MCF

where,

$$\text{MCF=Microscope Correction Factor} = \frac{\text{area of smear}}{\text{area of microscope field}} \times \text{dilution factor}$$

Area of Microscope field=πr^2

Radius of the microscope field=r

2.4. Inoculation

Sterile inoculating needle was dipped into the spore suspension containing 2.00×10^5 spores/ml and the needle was then dipped into healthy surface disinfected tomato fruit. The needle wound was then covered with vaspar; a mixture of Vaseline and paraffin (1:1).

2.5. Heat Treatment

The heat treatments used were

(i) 46°C Hot air for 1 hour (HA46^{1h})

(ii) 70°C Hot air for 4 minutes (HA704)

(iii) 70°C Hot air for 6 minutes (HA70^{6})

(iv) 48°C Hot water for 10 minutes (HW48^{10})

(v) 42°C Hot water for 25 minutes (HW42^{25})

(vi) Control which is untreated

Hot air was obtained using Gallenkamp oven and heated to the required temperature. The hot water treatment was carried out in a water bath heated to the required temperature. All treatments were replicated five times. After treatment, the fruits were stored in sterilized dessicators, placed on the side bench in the laboratory at 28°C±2°C. The controls were transferred into sterilized dessicators after inoculation without heat treatment.

2.6. Assessment of Disease Severity

The extent of decay of the fruits were measured as the disease severity on the scale of 1 – 5 where; 1 is healthy (no decay); 2 is little or slight decay on 20% - 30% decay on fruit; 3 is heavy decay on 50% - 60% decay on fruit; 4 is very severe on 70 – 80% decay on fruit and 5 is complete decay on more than 90% decay of fruit [6].

3. Results and Discussion

3.1. Effect of Heat Treatment on Disease Severity of Tomato

Table 1 shows the effect of heat treatment on disease severity of mature-green fruits. There was no sign of decay as at day 4 in the control and treated fruits except HW42^{25} and HA46^{1h} with mean of 1.20, but this was not significantly different from other treatments. The severity of disease observed in HA70^{4}, HW48^{10}, and HA46^{1h} treated fruits on day 5 was not significantly different from the disease severity observed in HW42^{25}which had the highest disease index with mean of 1.60 and HA70^{6}and control which had fruits which had no sign of spoilage. Result obtained on day 6 of storage showed no significant difference in severity of disease in all treated fruits. On the11th day of storage, complete spoilage was observed in HA46^{1h} with mean of 5.00 not significantly different from HA70^{6} with mean of 4.20. HA70^{4}, HW48^{10} and the control fruits had mean of 1.40, 1.40, and 1.60 respectively, not significantly different from mean of HW42^{25} treated fruits with 3.40.

On the third day of storage in breaker fruits, there was no sign of decay in all the treated fruits except control fruits with symptoms and mean of 1.40 which was significantly different from all treated fruits. By the fifth day, result showed no significant difference in the mean value obtained in all the treated fruits. On the sixth day of storage, both HA70^{4} and HW48^{10} had mean of 1.20 significantly different from other treated fruits. Control, HA70^{6}, HW42^{25} and HA46^{1h} had mean values of 2.60, 2.60, 2.40and 2.40 respectively. Both HA70^{4} and HW48^{10} continued to have mean value significantly different from other treated fruits till 11th day of storage. On the eleventh day of storage, both HA70^{4} and HW48^{10} had mean value of 1.40 which was significantly different from HW42^{25} with mean of 4.20, HA46^{1h} with mean of 4.40, HA70^{6} with mean of 5.00 and control with mean of 5.00. (Table 2).

Table 1. *Effect of heat treatment on the disease severity caused by F. nivale on mature-green tomato fruits during storage at 28±2°C.*

Treatments	Days of storage/Disease severity					
	1	2	3	4	5	6
Control	1.00±0.0^{a}	1.00±0.00^{a}	1.00±0.00^{a}	1.00±0.00^{a}	1.00±0.00^{a}	1.20±0.45^{a}
HA 70^{6}	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}
HW 42^{25}	1.00±0.00^{a}	1.00±0.00^{a}	1.00±0.00^{a}	1.20±0.45^{a}	1.60±0.55^{b}	1.80±0.84^{a}
HA 70^{4}	1.00±0.00^{a}	1.00±0.00^{a}	1.00±0.00^{a}	1.00±0.00^{a}	1.20±0.45^{ab}	1.20±0.45^{a}
HA 46^{1h}	1.00±0.00^{a}	1.00±0.00^{a}	1.00±0.45^{a}	1.20±0.45^{a}	1.40±0.55^{ab}	1.80±0.45^{a}
HW 48^{10}	1.00±0.00^{a}	1.00±0.00^{a}	1.00±0.00^{a}	1.00±0.00^{a}	1.20±0.45^{ab}	1.20±0.45^{a}

Table 1. *Continued.*

Treatments	Days of storage/Disease severity					Mean Total
	7	8	9	10	11	
Control	1.20±0.45^{a}	1.40±0.89^{a}	1.60±1.34^{a}	1.60±1.34^{a}	1.60±1.79^{a}	1.25±0.82
HA 70^{6}	2.20±0.84^{abc}	3.40±1.52^{b}	3.80±1.64^{b}	4.20±1.79^{b}	4.20±1.79^{b}	2.16±1.68
HW 42^{25}	2.40±1.34^{bc}	2.80±1.63^{ab}	3.00±1.87^{ab}	3.40±2.19^{ab}	3.40±2.19^{ab}	2.05±1.51
HA 70^{4}	1.20±0.45^{a}	1.20±0.45^{a}	1.40±0.89^{a}	1.40±0.89^{a}	1.40±0.89^{a}	1.18±0.51
HA 46^{1h}	3.00±0.00^{c}	4.00±0.00^{b}	4.20±0.45^{b}	4.80±0.45^{b}	5.00±0.00^{b}	2.60±1.59
HW 48^{10}	1.20±0.89^{a}	1.20±0.45^{a}	1.40±0.89^{a}	1.40±0.89^{a}	1.40±0.89^{a}	1.35±0.99

Means with the same superscript alphabets in a column are not significantly different (p>0.05) by Duncan's Multiple Range Test

Table 2. *Effect of heat treatment on the disease severity caused by F. nivale on breaker fruits of tomato fruits during storage at 28±2°C.*

Treatments	Days of storage/Disease severity					
	1	2	3	4	5	6
Control	1.00±0.00^{a}	1.00±0.00^{a}	1.40±0.55^{b}	1.60±0.55^{a}	1.60±0.55^{a}	2.60±0.55^{b}
HA 70^{6}	1.00±0.00^{a}	1.00±0.00^{a}	1.00±0.00^{a}	1.20±0.45^{a}	2.00±0.71^{a}	2.60±0.55^{b}
HW 42^{25}	1.00±0.00^{a}	1.00±0.00^{a}	1.00±0.00^{a}	1.20±0.45^{a}	1.80±0.45^{a}	2.40±0.89^{b}
HA 70^{4}	1.00±0.00^{a}	1.00±0.00^{a}	1.00±0.00^{a}	1.20±0.45^{a}	1.20±0.45^{a}	1.20±0.45^{a}
HA 46^{1h}	1.00±0.00^{a}	1.00±0.00^{a}	1.00±0.00^{a}	1.40±0.55^{a}	2.00±0.82^{a}	2.40±0.89^{b}
HW 48^{10}	1.00±0.00^{a}	1.00±0.00^{a}	1.00±0.00^{a}	1.00±0.00^{a}	1.20±0.45^{a}	1.20±0.45^{a}

Table 2. *Continued.*

Treatments	Days of storage/Disease severity					Mean Total
	7	8	9	10	11	
Control	3.80±0.45^{b}	4.20±0.84^{b}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}	2.93±1.68
HA 70^{6}	3.40±0.55^{b}	4.20±0.45^{b}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}	2.85±1.69
HW 42^{25}	3.40±1.34^{b}	3.80±1.64^{b}	4.20±1.79^{b}	4.20±1.79^{b}	4.20±1.79^{b}	2.56±1.73
HA 70^{4}	1.20±0.45^{a}	1.20±0.45^{a}	1.40±0.55^{a}	1.40±0.55^{a}	1.40±0.55^{a}	2.56±1.57
HA 46^{1h}	3.20±1.30^{b}	3.80±1.64^{b}	4.40±1.34^{b}	4.40±1.34^{b}	4.40±1.34^{b}	2.69±1.60
HW 48^{10}	1.20±0.45^{a}	1.40±0.55^{a}	1.40±0.55^{a}	1.40±0.55^{a}	1.40±0.55^{a}	2.53±1.67

Means with the same superscript alphabets in a column are not significantly different (p>0.05) by Duncan's Multiple Range Test

In turning fruits, spoilage became noticeable on the second day of storage in HW48^{10} with mean of 1.80 which was not significantly different from HW42^{25} with mean of 1.40. Fruits exposed to HW42^{25} were also not significantly different from HA70^{6} and HW46^{1h} with mean of 1.20 and control and HA70^{4} with mean of 1.00. By the fourth day, there was noticeable sign of decay in all the treated fruits and control. Both HA46^{1h} and control had mean of 2.00 not significantly different from HA70^{4} with mean of 1.20, and HA70^{6} with mean of 2.40, HW48^{10} with mean of 2.60 and HW42^{25} with mean of 2.80. On the fifth day, result obtained showed that HA70^{4} had mean value of 1.20 significantly different from others, HA46^{1h} had 2.60, control had 3.00, HW48^{10} had 3.20 and HW42^{25} had 3.60. On day 9, disease severity in HA70^{4} increased to 1.40 significantly different from HA70^{6} with mean of 4.80 and others which were completely spoilt. By day 11, HA70^{4} had attained mean of 1.60 significantly different from other treated fruit. (Table 3).

Table 4 shows the effect of heat treatment on disease severity of pink fruits of tomato. Spoilage was noticeable from the second day of storage in control with mean of 2.00 which was significantly different from the observation on HA46^{1h} treated fruits with mean of 1.60. HW48^{10} treated fruits had mean of 1.20 but was not significantly different from other treated fruits with no evident sign of spoilage. By the fifth day of storage, the control, HW42^{25} and HA46^{1h} had means of 3.80, 3.80 and 3.60 respectively. This was significantly different from the mean obtained in HW48^{10} treated fruits with mean of 2.60. There was no significant difference in mean obtained in HA70^{6} treated fruits (3.00) and that obtained in HW42^{25}, control, HA46^{1h} and HW48^{10}. By day 7 of storage, the least disease index was observed in HA70^{4} with mean of 4.40 while HW42^{25} and HA46^{1h} treated fruits were completely spoilt. On the eighth day of storage, complete spoilage was observed in all the treated fruits and control.

Table 3. *Effect of heat treatment on the disease severity caused by F. nivale on turning fruits of tomato fruits during storage at 28±2°C.*

Treatments	Days of storage/Disease severity					
	1	2	3	4	5	6
Control	1.00±0.00^{a}	1.00±0.00^{a}	1.40±0.55^{ab}	2.00±0.71^{ab}	3.00±0.71^{b}	3.80±0.84^{b}
HA 70^{6}	1.00±0.00^{a}	1.20±0.45^{a}	1.40±0.55^{ab}	2.40±1.14^{b}	3.00±1.22^{b}	3.40±1.14^{b}
HW 42^{25}	1.00±0.00^{a}	1.40±0.55^{ab}	2.20±1.10^{b}	2.80±0.84^{b}	3.60±0.89^{b}	4.20±0.45^{b}
HA 70^{4}	1.00±0.00^{a}	1.00±0.45^{a}	1.00±0.71^{a}	1.20±0.45^{a}	1.20±0.45^{a}	1.20±0.45^{a}
HA 46^{1h}	1.00±0.00^{a}	1.20±0.45^{a}	1.60±0.55^{ab}	2.00±0.71^{ab}	2.60±0.55^{b}	3.60±0.55^{b}
HW 48^{10}	1.00±0.00^{a}	1.80±0.45^{b}	2.00±0.00^{b}	2.60±0.55^{b}	3.20±0.45^{b}	3.80±0.84^{b}

Table 3. *Continued.*

Treatments	Days of storage/Disease severity					Mean Total
	7	8	9	10	11	
Control	4.60±0.55^{b}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}	3.35±1.70
HA 70^{6}	4.20±0.84^{b}	4.80±0.45^{b}	4.80±0.45^{b}	4.80±0.45^{b}	4.80±0.45^{b}	3.25±1.64
HW 42^{25}	4.60±0.55^{b}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}	3.62±1.56
HA 70^{4}	1.20±0.45^{a}	1.20±0.45^{a}	1.40±0.55^{a}	1.40±0.55^{a}	1.60±0.55^{a}	3.18±1.52
HA 46^{1h}	4.40±0.55^{b}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}	3.31±1.64
HW 48^{10}	4.40±0.55^{b}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}	5.00±0.00^{b}	3.53±1.48

Means with the same superscript alphabets in a column are not significantly different ($p>0.05$) by Duncan's Multiple Range Test

Table 4. *Effect of heat treatment on the disease severity caused by F. nivale on pink fruits of tomato Fruits during storage at 28±2°C.*

Treatments	Days of storage/Disease severity					
	1	2	3	4	5	6
Control	1.00±0.00^{a}	2.00±0.00^{c}	2.80±0.45^{c}	3.60±0.55^{c}	3.80±0.84^{c}	4.60±0.55^{cd}
HA 70^{6}	1.00±0.00^{a}	1.00±0.00^{a}	1.40±0.55^{ab}	2.40±0.55^{b}	3.00±0.71^{bc}	4.00±0.71^{bc}
HW 42^{25}	1.00±0.00^{a}	1.00±0.00^{a}	1.20±0.45^{a}	2.60±0.55^{b}	3.80±0.45^{c}	4.60±0.55^{cd}
HA 70^{4}	1.00±0.00^{a}	1.00±0.00^{a}	1.00±0.00^{a}	1.40±0.55^{a}	1.40±0.55^{a}	2.60±0.55^{a}
HA 46^{1h}	1.00±0.00^{a}	1.60±0.55^{b}	2.80±0.45^{c}	3.60±0.55^{c}	3.60±0.55^{c}	5.00±0.00^{d}
HW 48^{10}	1.00±0.00^{a}	1.20±0.45^{a}	2.00±0.71^{b}	2.60±0.55^{d}	2.60±0.55^{b}	3.80±0.45^{b}

Table 4. *Continued.*

Treatments	Days of storage/Disease severity					Mean Total
	7	8	9	10	11	
Control	4.60±0.55^{ab}	5.00±0.00^{a}	5.00±0.00^{a}	5.00±0.00^{a}	5.00±0.00^{a}	3.85±1.38
HA 70^{6}	4.80±0.45^{ab}	5.00±0.00^{a}	5.00±0.00^{a}	5.00±0.00^{a}	5.00±0.00^{a}	3.42±1.69
HW 42^{25}	5.00±0.00^{b}	5.00±0.00^{a}	5.00±0.00^{a}	5.00±0.00^{a}	5.00±0.00^{a}	3.56±1.72
HA 70^{4}	4.40±0.55^{a}	5.00±0.00^{a}	5.00±0.00^{a}	5.00±0.00^{a}	5.00±0.00^{a}	2.98±1.83
HA 46^{1h}	5.00±0.00^{b}	5.00±0.00^{a}	5.00±0.00^{a}	5.00±0.00^{a}	5.00±0.00^{a}	3.87±1.47
HW 48^{10}	4.80±0.45^{ab}	5.00±0.00^{a}	5.00±0.00^{a}	5.00±0.00^{a}	5.00±0.00^{a}	3.45±1.60

Means with the same superscript alphabets in a column are not significantly different ($p>0.05$) by Duncan's Multiple Range Test

In light red fruits, significant signs of spoilage were observed on day 2 in control fruits and HA46^{1h} treated fruits with mean of 1.80 and 2.00 respectively. Spoilage was also observed in HW42^{25} treated fruit but was not significant. On the fourth day of storage, HA70[4] treated fruits had a mean value of 2.00 which was not significantly different from HA70[6] treated fruits with the least disease index and HW42[25] and HW48[10] treated fruits both with mean value of 2.80. The HA46[1h]treated fruits had the highest mean value of 3.80. By day 7, there was no significant difference in disease index observed in all treated fruits; complete spoilage was observed on the eighth day of storage in all the treated fruits. (Table 5).

In red fruit, spoilage was evident in all the treated fruits beginning from day 2 (Table 6). The disease index observed in day 2 in all treated fruits and control was not significantly different from one another, likewise on day 3 of storage. On the fifth day of storage, HA70[4] treated fruits had the least mean value of disease severity with 2.80. This was not significantly different from HW48[10] and HA70[6] treated fruits which had mean value of 3.20 and 3.60 respectively. Fruits exposed to HA46[1h] had a mean value of 4.00 which was not significantly different from the control and HW42[25] treated fruits with the highest values 4.40 and 4.60 respectively. From the seventh day of storage to the eleventh day, complete spoilage was observed in all the treated fruits and control except HW48[10] but was not significantly different from others through this period of days.

Table 5. *Effect of heat treatment on the disease severity caused by F. nivale on light red fruits of tomato fruits during storage at 28±2°C.*

Treatments	Days of storage/Disease severity					
	1	2	3	4	5	6
Control	$1.00±0.00^a$	$1.80±0.45^b$	$3.20±0.84^c$	$3.60±0.89^c$	$4.20±0.84^{bc}$	$4.40±0.55^b$
HA 70^6	$1.00±0.00^a$	$1.00±0.00^a$	$1.00±0.00^a$	$1.20±0.45^a$	$2.20±0.45^a$	$3.20±0.84^a$
HW 42^{25}	$1.00±0.00^a$	$1.40±0.55^a$	$2.20±0.45^b$	$2.80±0.45^{bc}$	$3.20±0.45^{ab}$	$4.20±0.84^b$
HA 70^4	$1.00±0.00^a$	$1.00±0.00^a$	$1.20±0.45^a$	$2.00±0.00^{ab}$	$2.40±0.55^a$	$4.00±0.71^{ab}$
HA 46^{1h}	$1.00±0.00^a$	$2.00±0.00^b$	$3.00±0.00^{bc}$	$3.80±0.45^c$	$4.40±0.55^c$	$4.60±0.55^b$
HW 48^{10}	$1.00±0.00^a$	$1.00±0.00^a$	$2.20±1.30^b$	$2.80±1.30^{bc}$	$3.60±1.34^{bc}$	$4.00±0.71^{ab}$

Table 5. *Continued.*

Treatments	Days of storage/Disease severity					Mean Total
	7	8	9	10	11	
Control	$4.60±0.71^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	3.89±1.41
HA 70^6	$4.80±0.45^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	3.13±1.83
HW 42^{25}	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	3.62±1.55
HA 70^4	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	3.33±1.75
HA 46^{1h}	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	3.98±1.37
HW 48^{10}	$4.60±0.90^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	3.56±1.68

Means with the same superscript alphabets in a column are not significantly different (p>0.05) by Duncan's Multiple Range Test

Table 6. *Effect of heat treatment on the disease severity caused by F. nivale on red-ripe fruits of tomato fruits during storage at 28±2°C.*

Treatments	Days of storage/Disease severity					
	1	2	3	4	5	6
Control	$1.00±0.00^a$	$1.40±0.55^a$	$2.40±0.55^a$	$3.60±0.55^b$	$4.60±0.55^c$	$5.00±0.00^a$
HA 70^6	$1.00±0.00^a$	$1.40±0.55^a$	$2.00±0.00^a$	$2.60±0.55^{ab}$	$3.60±0.55^{ab}$	$4.40±0.55^a$
HW 42^{25}	$1.00±0.00^a$	$1.80±0.45^a$	$2.00±0.00^a$	$3.60±0.55^b$	$4.40±0.55^c$	$5.00±0.00^a$
HA 70^4	$1.00±000^a$	$1.20±0.45^a$	$1.80±0.45^a$	$2.20±0.84^a$	$2.80±0.45^a$	$4.20±0.45^a$
HA 46^{1h}	$1.00±0.00^a$	$1.20±0.45^a$	$2.20±0.45^a$	$3.20±0.45^{ab}$	$4.00±0.71^{bc}$	$4.60±0.55^a$
HW 48^{10}	$1.00±0.00^a$	$1.20±0.45^a$	$2.00±0.71^a$	$2.80±1.30^{ab}$	$3.20±1.30^{ab}$	4.00±1.73

Table 6. *Continued.*

Treatments	Days of storage/Disease severity					Mean Total
	7	8	9	10	11	
Control	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	3.91±1.54
HA 70^6	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	3.64±1.57
HW 42^{25}	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	3.89±1.51
HA 70^4	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	3.47±1.65
HA 46^{1h}	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	$5.00±0.00^a$	3.75±1.57
HW 48^{10}	$4.00±1.70^a$	$4.20±0.73^a$	$4.20±1.70^a$	$4.40±1.34^a$	$4.40±1.34^a$	3.18±1.78

Means with the same superscript alphabets in a column are not significantly different (p>0.05) by Duncan's Multiple Range Test

3.2. Discussion

The results of this research show that both hot water and hot air were effective in reducing disease index in tomato. All the hot air treatment (HA70[4], HA70[6]and HA46[1h]) used in this study were effective in the control of *F. nivale* on tomatoes. In mature-green fruits, HA70[6] and HA46[1h] inhibited decay for 6 days; they also inhibited decay for 4 days in breaker fruits. HA70[4] inhibited decay throughout storage in mature green, breaker and turning fruits, providing an effective protection against *F. nivale*. Hot air treatment of mango fruit at 48°C for 150 minutes and 46°C for 195 minutes was reported to reduce anthracnose by McGuire [9]. [10] reported that 38°C hot air for 72 hours sufficiently inhibited growth of *A. alternata* and *B. cinerea* on tomatoes. In contrast, [11] reported that the treatment of papaya fruit with air 48.5°C for 3-4 hours did not significantly reduce postharvest disease.

Using hot water to control *F. nivale* on tomatoes also proved to be effective on this study. $HW42^{25}$ inhibited decay in mature green tomatoes for 6 days and in breaker fruits for 5 days. $Hw48^{10}$ inhibited decay in mature-green and breaker fruits for 11 days. The effectiveness of hot water at 52°C for 15seconds in the reduction of decay development on tomatoes was reported by [12]. [13] noted that hot water at 40°C for 5 and 10 minutes inhibited decay caused by *Monilinia fructicola* in peach fruit. In the same trend, dipping cantaloupe fruit inoculated with *Fusarium simectectum, Cladosporum herbarum and Alternaria alternata* in hot water at 50°C for 2.5, 5 and 10 minutes as reported by [14] inhibited decay by these fungi. Immersion of Oranges inoculated with *Penicillium digitatum* in hot water (75°C for 150 minutes) reduced decay by 90% when compared with control fruits [15]. In the same trend, green mould of tangerine was controlled by floating the fruit in 55°C hot water for 2-3 minutes [16]. Hot water at 45°C for 30 minutes and 47°C for 15 minutes was reported by [17] to make 'Kensington' mangoes resistant to postharvest disease. [18] also reported that hot water treatment of Boui mango at 52°C for 5 minutes reduced development of postharvest diseases. Hot water at 49°C for 29 minutes was reported by [11] to effectively control postharvest diseases of papaya fruit. [19] reported that part of the effect of hot water is due to its potential to remove spores from the wounds and also the direct effect of high temperature on the pathogenic agent.

In green tomatoes, development of decay was inhibited by the treatments (both hot air and hot water) for at least 5 days; while decay was inhibited all through storage in control. This shows that the inability of $HA46^{1h}$, $HA70^{6}$, and $HW42^{25}$to reduce disease severity for more than 6 days could be as a result of heat stress. Likewise in breaker, disease was inhibited for 5 days in control and $HW42^{25}$ treated fruits and for four days in $HA70^{6}$ and $HA46^{1h}$. $HA70^{4}$ and $HW48^{10}$ inhibited decay for 11 days. Decay was also inhibited for at least 3-days in turning fruits by all the treatment except $HA70^{4}$. Heat stress and pathological stress on the fruit could be the reason for the inability of the fruit to inhibit decay for longer period. In pink, only $HA70^{4}$ inhibited decay for 5-days, while others could only inhibit decay for maximum of three days. In light red fruits, decay was inhibited by the treatment for at least 1 day ($HA46^{1h}$) and at most four days ($HA70^{6}$) while in red inhibition of decay was for a period of two days minimum in control, $HA70^{4}$, $HW42^{25}$, $HA46^{1h}$ and $HW48^{10}$ while it was for 3 days with $HA70^{4}$ treatment. The combination of heat stress and pathological stress coupled with ripening process may be the cause of the inability of the treatment to inhibit decay for longer periods.

The result presented reveals that heat treatment (hot air and hot water) has the ability to inhibit decay in tomato for different days. However, further studies are underway to understand how the fungi are inhibited as well as the effect on the fruit quality. This is necessary to reveal the safety of the method on fruits

4. Conclusion

This study has demonstrated the effectiveness of heat treatment in the preservation of tomato fruits; revealing that HA704 was most suitable in preserving mature-green, breaker, turning, pink and red-ripe tomato fruits, while HA706 was effective in preserving light red fruits. HW4810 also proved very efficient in the preservation of mature-green and breaker tomato fruits, however, the effectiveness of the heat treatment used depend on the ripening stage of the fruit and the duration of storage.

References

[1] Shankara, N., Joep, J., Maria, G. Martin, H. And Barbara, D. (2005). Cultivation of Tomato in: Production, Processing and Marketing. D. Barbara. (eds) Digigrati Publishers, Wageninger, the Netherlands.

[2] Coates, L. M. and Johnson, G. I. (1991). Postharvest diseases of fruits and vegetables pp 533–547.

[3] Conway, W. S., Leverentz, B., Janisiewicz, W. J., Saftner, R. A. and Camp, M. J., (2005). Improving biocontrol using antagonist mixtures with heat and/or sodium bicarbonate to control post harvest decay of apple fruit. *Postharvest Biology Technol*ogy 36, 235–244.

[4] Fallik, E. (2004). Prestorage hot water treatments (immersion, rinsing and brushing). *Postharvest Biology Technology* 32: 125–134.

[5] Banyal, D. K., Mankotia, V. and Sugha, S K. (2008). Integrated management of tomato collar rotcaused by *Sclerotiumrolfsii*. *J. Mycol. Plant Pathol*. 38: 165-167.

[6] Aborisade, A. T. and Ojo, F. H. (2007). Effect of post harvest hot air treatment of tomatoes (*Lycopersiconesculentum* Mill) on storage life and decay caused by *Rhizopus stolonifer*. *Journal of Plant Diseases and Protection* 109: 639-645.

[7] Fallik, E., Aharoni, Y., Yekutieli, O., Wiseblum, A., Regev, R., Beres, H. and Bar Lev, E., (1996). A method for simultaneously cleaning and disinfecting agricultural produce. Israel Patent Application No. 116965.

[8] Ogundana S. K. (1989). "Introductory Microbiology" A Laboratory Manual, O. A. U. Press, Ile –Ife, Nigeria. pp 143-147.

[9] Mcguire, R. G. (1991). Concomitant decay reductions when mangoes are treated with heat to control infestations of Caribbean fruit fly. *Plant Disease* 75: 946-949.

[10] Tohamy, M. R. A., Helal, G. A., Ibrahim K. I. and Abd-el-aziz, S. A. (2004). Control of Postharvest Tomato Fruit Rots: Using Heat Treatments. Egypt. *Journal of Phytopathology* 32: 129-138.

[11] Nishijima, K. A., Miura K., Armstrong, J. W., Brown, S. A., and Hu, B. K. S. (1992). Effect offorced, hot-air treatment of papaya fruit on fruit quality and incidence of postharvest diseases. *Plant Disease* 76: 723-727.

[12] Ilic, Z., Polevaya, Y., Alkalai-Tuvia, S., Copel, A. and Fallik, E. (2001). A short prestorage hotwater rinse and brushing reduces decay development in Tomato while maintaining its quality. *Tropical Agricultural Research and Extension* 4: 425-428.

[13] Liu, J., Sui, Y., Wisniewski, M., Droby, S., Tian, S., Norelli, J. And Hershkovitz, V. (2012). Effect of heat treatment on inhibition of Monilinia fructicola and induction of disease resistance in peach fruit. *Postharvest Biology and Technology* 65: 61–68

[14] Nafaa and Azza M. A. K. (2001). Minimizing chemical use in controlling postharvest disease of cantaloupe Ph.D. Thesis, Fac. Agric., Ain Shams Univ., Egypt, 138pp.

[15] Palou, L., Smilanick, J. L., Usuall, J. and Vinas, I. (2001). Control of postharvest blue and greenmoulds of oranges by hot water, sodium carbonate, and sodium bicarbonate. *Plant Disease* 5: 371-376.

[16] Smilanick, J. L., Mansour, M. F., Galber, F. G and Sorenson, D. (2008). Control of citruspost harvest green mold and sour rot by potassium sorbate combined with heat and fungicides. *Postharvest. Biology Technology*: 226-38.

[17] Jacobi, K. K., Mcrae, E. A. and Hetherington, S. E. (2000). Effect of hot air conditioning of Kensington mango fruit on the response to hot water treatment. *Postharvest Biology and Technology* 21: 39-49.

[18] Nguyen, H. X., Opara, L. U. and To, L. V. (1998). Hot water treatment affects fruit mass loss and incidence of postharvest diseases and disorders in “Buoi” mango (*Mangifera indica* Linn.). *Journal. of Southern Pacific Agricultur* 5: 13-18.

[19] Fatemi, S. and Borji, H. (2011). The effect of physical treatments on control of P*enicilliumdigitatum* decay orange cv. Valencia during storage period. *African Journal of Agricultural Research* 6: 5757-5760.