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EFFECT OF HOT WATER TREATMENT ON POSTHARVEST FRUIT ROTS AND QUALITY OF TOMATO FRUITS

Manal M. Yasser[1], Marym M. Marzouk[1]*, Taghrid A. Kamel[2] and Azza M. A. Naaffa[2]

[1*]Department of Botany& Microbiology, Faculty of Science, Beni-Suef University, Egypt.
[2]Plant Pathology Research Institute, Agricultural Research Center, Giza, Egypt.

Abstract

The possibility of using hot water treatment to reduce the postharvest losses of tomato fruits during marketing and storage was assessed against *Alternaria alternata*, *Botryits cinerea* and *Geotrichum candidum* (Ascomycota) which cause black mould, grey mould and sour rot, respectively. Healthy hybrids; 5047, 935 and 55 of tomato fruits were used in this study. The naturally decayed and the artificially inoculated fruits were treated with hot water at 45, 50 and 55^{0}C, for three, five and seven minutes. Our results showed that treatment at 55^{0}C for seven minutes have the highest effect to prevent decay development in both naturally and artificially inoculated fruits with *G. candidum* and significantly decreased the decay in the artificially inoculated fruits with *B. cinerea* and *A. alternata.* Moderate effects at 50^{0}C and 45^{0}C were observed. Measuring the quality parameters of tomato fruits showed increased firmness, decreased weight loss and high content of the total soluble solids for hot water-treated fruits.

Key words: Tomato fruits, *Alternaria alternata, Botryits cinerea*, *Geotrichum candidum*, Hot water treatment

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is a member of the family *solanaceae* and is one of the most economic vegetable crops in Egypt for local consumption and exportation purposes. It is one of the most popular vegetable crops for its edible fruits, high nutritive values and also for its diversified uses (Afroz *et al*., 2008); (Ewulo *et al*., 2008). Tomato holds the first rank in the relative contribution to human nutrition when compared to 39 major fruits and vegetables (Saltueit, 2003). The composition of tomato is believed to benefit the health as they contain lycopene, one of the most powerful natural antioxidant which helps in preventing prostate cancer, heart disease and muscular degeneration (Olson, 2004); (Wener, 2008).

Tomato is a healthy food with low fat, cholesterol free and a good source of fiber and protein (Masyitah, 2004). One medium sized tomato provide 40% of the Recommendation Daily Allowance (RDA) of vitaminC (Ascorbic acid), 20% of the RDA of vitamin A, substantial amount of potassium, calcium and lesser amount of iron, magnesium, thiamine, riboflavin and niacin, yet contain only about 35 calories (Olson, 2004). Fruit rots are important post-harvest diseases of tomato that occur during harvesting and/or improper storage and marketing conditions. Postharvest diseases destroy 10-30% of the total yield of crops and in some perishable crops like tomato especially in developing countries; they destroy more than 30% of the crop yield (Kader, 2002); (Agrios, 2005).

Tomato fruit has been greatly affected by fungi infection during storage and potentially causes serious reduction in quality and market value of the product (Friedman, 1960).Postharvest losses have thus been identified as one of the determinants of food problems in most developing countries.

The principal fungal fruit rots reported all over the world with varying intensities on tomato includes Alternaria rot caused by *A. solani* and *A. tenuis,* Phytophthora rot caused by *Phytophthora infestans, Phytophthora nicotianae* var. *parasitica,* Anthracnose ripe rot caused by *Colletotrichum phomoides*, Phoma rot *caused by Phoma destrructiva* and Fusarium rot caused by *Fusarium* spp. and sour rots caused by *Geotrichum*

***Author for correspondence :** E-mail: ritapaul2000@gmail.com

candidum (Moline, 1984); (Ghafoor and Haqqani, 2003); (Ali *et al*., 2005); (Patel *et al*., 2005).

Alternaria alternata and *Botryits cinerea* are the two main fungi responsible for storage decay of tomato in Egypt (EL-Essawy *et al*., 2003).

Heat treatments have been used to control fungal disease since the first decades of the 20th Century, when the effectiveness of hot water in controlling molds in citrus was reported. Trials with different citrus species including tangerines, oranges, lemons and grapefruits showed that applications of water at 50-60^{0}C for 10-20sec effectively reduced green mold and other diseases with no rind injuries or adverse influence on fruit weight loss and internal quality (Porat *et al*., 2000); (Rodov *et al*., 2000). Since then, multiple additional benefits such as chilling tolerance, extension of shelf life and preservation of fruit quality have been revealed the increasing concern about the use of synthetic fungicides, perceived as harmful to human health and to the environment is to contribute to the growing interest in the development of environmentally friendly method for postharvest management. Apart from reducing the dependence on agrochemicals, heat treatment possess the appealing advantage of being relatively simple to apply, as they can sometimes be incorporated into packinghouse sorting lines perceived as safe and friendly. The increased demands for pesticide-free products and restrictions on the use of chemical treatments have revived interest in the use of non-chemical procedures such as heat treatment (Lurie, 1998); (Karasahim *et al*., 2005). Heat treatment control fruit decay via direct germicidal effect on pathogens and by melting and spreading the distribution of cuticular waxes on the fruit surface so limiting the sites of pathogen penetration. These strategies have been recently studied in diverse commodities. Liu *et al.,* (2012) treated peaches with hot water at 40^{0}C for 10 min and indicated that decay control was due to a direct effect of the heat on *Monilia fructicola* associated with an increase in intracellular reactive oxygen species, mitochondrial dysfunction and a decrease in ATP; and on the host, by enhancing the defense-related enzyme phenylalanine ammonia lyase in the fruit. Li *et al.,* (2013) showed that treatment of papaya with hot water at 54^{0}C for 4 min controlled *colletotrichum gloeosporioides* in the fruit peel by inducing the local expression of defense–related proteins. In addition, heat melted the fruit wax creating a mechanical barrier against pathogen penetration. Similar results were also obtained by Yuan *et al*., (2013) who studied the effects of hot water dipping at 53^{0}C for 3 min in muskmelon. The treatments reduced decay caused by *Trichothecium roseum*, *Alternaria alternata*, *Fusarium spp* and *Rhizopus stolonifer.* The treatments cleaned the surface of the fruit and melted the epicuticular waxes, covered and sealed stomata and also enhance the activities of the defense–related enzymes phenylanine ammonia lyase,cinnamate-4-hdroxy lase, 4-coumarate:co aligase, polyphenoloxidase and peroxidase. Jemric *et al*., (2013) showed that nectarines treated with hot water immersion at 48^{0}C for 6-12 min followed by storage at 0^{0}C for 2 weeks, nectarine heated for 12 min achieved better sensory scores for firmness, texture, sugar acidity ratio and general appearance.

Heat treatments have already been used to control postharvest decays and improving storage quality of kiwifruits (Femenia *et al*., 2009). Jacobi *et al.,* (2000) reported that Mango fruits were most resistant to postharvest diseases by hot water at 45^{0}C for 30 min or 47^{0}C for 15 min. In another study, Nafaa (2001) found that dipping cantaloupe fruits, inoculated with *Alternaria alternata*, *Fusarium simetectum, Cladosporium herbarum* in hot water at 500C for 2.5, 5 and 10 min. has inhibited decay by these fungi. Several studies reported that heat treatments increase heat shock proteins, antioxidant enzymes and phytochemicals such as carotenoids and phenolic compounds (Ummarat *et al*., 2011). Ghasemnezhad *et al*., (2008) found that an increase in superoxide dismutase, peroxidase and catalase activities after hot water treatments in mandarins. Talcott *et al.,* (2005) found an increase in polyphenols and carotenoids which resulted in great antioxidant activity in hot water-treated mangoes when compared to untreated fruits. These results indicate that heat treatments prolong postharvest life of some fruits and promote the increase of bioactive compounds (Gonzalez-Aguilar *et al.,* 2010).

The present work aims to evaluate the effect of treating tomato fruits by hot water on reducing rot decay during marketing and storage and on the quality parameters of tomato fruits such as firmness (FF), total soluble solids (TSS) and loss in weight (LW).

Materials and Methods

Isolation of fungi causing fruit rots of tomato

To isolate fungi causing tomato fruit decay, a total of 210 samples of natural infected tomato fruits were collected from Giza, Beni-Suef, representing the most governorates producing tomatoes in middle Egypt and Kafr-elsheikh, Minufiya representing the most governorates producing tomatoes in lower Egypt. Fruits exhibiting symptoms of spoilage were brought into the microbiology laboratory for the isolation of pathogens in the Agricultural Research Center, Giza, Egypt. Rotted fruits were washed with clean water then surface sterilized

with 70% ethyl alcohol and dried for one minute using sterile filter paper. A sterile scalpel used to cut 3mm × 3mm section of tissue from the tomato moving from the healthy portion to the diseased portion where fungi are likely to be more active. Cut portions of tomato were aseptically placed on potato dextrose agar in Petri plates and incubated for four days at ambient temperature of $25^0C \pm 3^0C$. The set up were observed for 7-10 days until the organism became fully grown. Pure culture of the isolates was obtained after series of inoculations into sterile potato dextrose agar.

The frequency of fungi for each governorate was measured by using the formula as follow:

$$\%\,frequency = \frac{Number\,of\,isolated\,certain\,fungus}{Total\,number\,of\,\,fungi\,per\,governorate} \times 100$$

Pathogenicity test

To test the pathogenicity of the isolated fungi towards tomato fruits, 3mm agar discs 7 days for *A. alternata*, 10 days for *B. cinerea* and 15 days for *G. candidum* each fungus were inoculated into small scratched wounds made into apparently healthy tomato fruits which were washed with sterile distilled water and surface sterilized with 70% ethyl alcohol. Three replicates were used, each containing nine fruit. The inoculated fruits were put in sterilized carton box with 5kg capacity and kept at room temperature (20-25^{0}C) for 10 days. The resulted rot was measured using the decay index and severity of infection according to Chastanger and Ogawa (1979) based on visual inspection of each fruit infection. Infected fruits were placed in one of five categories:

0 = superficial fleck (no soft decay).

1 =1-24% of the surface decayed.

2 =25-49% of the surface decayed.

3 =50-74% of the surface decayed.

4=75%or more of the surface decayed.

Decay index (DI) for each treatment was obtained as follows:

$$DI = \frac{Sum\,(number\,of\,\,fruits\,per\,category \times category\,number)}{Total\,no\,of\,\,fruits}$$

% severity of infection = (DI/ 4) × 100

Hot water treatment

Healthy tomato fruits of uniform size of hybrids 5047, 935 and 55 at mature green stage apparently free of physical damage and diseases were used in this experiment. Fruits were divided into two lots. The first one divided into two groups which were surface sterilized with 70% ethyl alcohol for one minute, air dried and inoculated with 3mm of fungal mycelial disks of *Alternaria alternata*, *Botrytis cinerea* and *Geotrichum candidum* through very small scratch in the middle surface of each fruit. The second lot comprises also two groups of fruits which were left without inoculation. After 24 hours, one group, of each lot (un-inoculated and showed naturally decay fruits as well as inoculated fruits and showed the artificially decay fruits) was dipped in hot water at 45, 50 and 55^{0}C for 3, 5 and 7 min for each degree. The other two groups of each lot (the un-inoculated and inoculated fruits) were immersed in sterile water and served as control.

For each treatment three replicates were used. Each replicate contains nine fruits in sterilized carton box of 5kg capacity. The boxes were incubated at 13^{0}C and 90-95% relative humidity. Tomato fruits were examined weekly for detection of decay symptoms of the fungal pathogens.

Percentage of disease severity (DS) for symptoms of the three pathogens was assessed after one, two and three weeks of incubation. DS was calculated using formula adopted by Chastanger and Ogawa (1979)

The decay index (DI) for each treatment was obtained as follows:

$$DI = \frac{Sum\,(number\,of\,\,fruits\,per\,category \times category\,number)}{Total\,no\,of\,\,fruits}$$

% severity of infection = (DI/ 4) × 100

Tomato fruits quality parameters

Quality parameters of tomato fruits as fruit firmness (FF), total soluble solids (TSS) and loss in weight (LW) were determined 3 weeks after inoculation for both the inoculated and non- inoculated fruits.

Total soluble solids (TSS)

The total soluble solids (TSS) was determined by Hand refractometer recorded as direct reading from the instrument reported as Brix. The resolution by placing enough juice to cover the refractometer prism. Between samples the prism of the refractometer was washed with distilled water and dried before use.

Fruit firmness (FF)

Fruit firmness was measured using a penetrometer (a pressure tester 8mm plunger) and the firmness of the flesh was expressed as Newton (N).The start of penetration test was the contact of the probe and tomato surface and finish when the probe penetrated the tissues to depth of 8mm.

The point where the needle stopped was recorded as the value for the fruit firmness in kg cm-2. Each tomato

was punctured three times around the equatorial area and mean value was reported.

Loss in weight (LW)

Losses in tomato fruits fresh weight % (grams fresh weights %) were estimated in the inoculated and non-inoculated tomato fruits for all treatments (average weight of 27 fruits for each treatment) according to the following formula:

$$\%LW = \frac{Initial\ weight - weight\ at\ sampling\ date}{Initial\ weight} \times 100$$

Statistical analysis:

All data obtained were subjected to the proper Statistical analysis using the MSTAT statistical software and comparison was made following Fishers L.S.D. ($P<0.05$).

Results

A total of 114 fungal isolates belonging to seven different species were isolated from naturally infected tomato fruits which collected from different localities of some Egyptian governorates; Beni-Suef, Giza, kafr-elsheikh, Menoufia representing the most governorates producing tomatoes in Egypt.

Giza governorate showed the highest number of isolated fungal isolates (61) followed by Beni-Suef governorate (24), Minufiya (23) and Kafr-elsheikh (6) (Table 1).

The identification of isolated fungi was confirmed in fungal taxonomy department, Plant Pathology Institute, Agricultural Research Center, Giza, Egypt. (Barnett and Hunter, 1998).

Botrytis cinerea exhibited the highest percentage of infection (89.8%) followed by *Alternaria alternate* (80.6%) and *Geotrichum candidum* (72.2%). On the other hand, the lowest percentage of infection on tomato fruits was recorded by *Epicoccum* sp (12.9%) (Table 2)

Data in table 3 indicated that, In case of using hybrid 2, *A. alternata* was completely inhibited (0% severity of infection) at 50ºC/5 min and 55ºC/3 min while *B. cinerea* was completely suppressed at 45ºC/7 min, 50ºC/5 min and 55ºC/7 min and *G. candidum* was inhibited at 45ºC/5 min, 7 min and 55ºC/7 min. The treatment of hot water was not able to inhibit the pathogen in case of the other two hybrids (1 and 3) except in case of hybrid 3 which were artificially inoculated with *G. candidum* where its growth was completely suppressed at 45ºC/5 min and 55ºC/7 min. (Table 3).

Tomato fruits quality parameters:

Hot water treatments increased total soluble solids in naturally and artificially inoculated with *A. alternata, B. cinerea and G. candidum* in Tomato fruits hybrids (Table 4).

Hot water treatments 55 ºC/7 min showed the highest increase in tomato TSS in hybrid 935, hybrid 55 and hybrid 5047, respectively. Hybrid 935 (5.8, 6.2, 6), hybrid 55 (5.6, 5.9, 5.8) and hybrid 5047(5, 5.5, 5.4). *Botrytis cinerea* show the least negative effect on the content of the total soluble solids of the three tomato fruit hybrids (5.5, 6.2, 5.9) followed by *Geotrichum candidum*, (5.4, 6, 5.8) *Alternaria alternata* (5, 5.8, 5.6).

Hot water treatments also increased Firmness compared to the control in naturally and artificially inoculated fruits with *A. alternata, B. cinerea and G. candidum* in Tomato fruits hybrids. The treatment 45ºC/3 min showed the highest degree of firmness in hybrid 935(32.34, 32.34, 34.3) followed by hybrid 55(30.38,

Table 1: Frequency and percentages of isolated fungi from rotted tomato fruits collected from different Governorates.

Fungi	Governorates									Mean
	Giza		Minufiya		Beni-Suef		Kafr-elsheikh		Total	
	Nu	%F	Nu	%F	Nu	%F	Nu	%F		
Alternaria alternata	10	16.5	11	45.8			1	16.7	22	5.5
Aspergillus Niger	1	1.6	5	20.8	-	-	-	-	6	1.5
Botrytis cinerea	30	49.2	-	-	5	21.74	-	-	35	8.75
Epicoccum sp.	1	1.6	8	33.3	-	-	-	-	9	2.25
Fussarium oxysporum	8	13.1			1	4.35	5	83.3	14	4.5
Rhizopus stolonifera	1	1.6	-	-	-	-	-	-	1	0.25
Geotrichum candidum	10	16.4	-	-	17	73.91	-	-	27	6.75
Total	61	100	24	100	23	100	6	100	114	28.5
Mean	8.71	3.43	3.29	0.86	16.29					

Nu: Number of isolated fungi

%F: Percentage of frequency

Table 2: Percentage of infection for fungi isolated from rotted tomato fruits.

Fungi	%severity of infection
Alternaria alternata	80.6
Aspergillus niger	38.89
Botrytis cinerea	89.8
Epicoccum sp	12.9
Fusarium oxysporum	55.56
Rhizopus stolonifera	60. 2
Geotrichum candidum	72.2
L.S.D at 0.05 %	3.2

30.38, 32.34) and then hybrid 5047(30.38, 27.44, 30.38). On the other hand the lowest degree of firmness was recorded at 55ºC/7 min for *Geotrichum candidum* show (30.38, 34.3, 32.34) the least decrease in the firmness of the three tomato fruit hybrids followed by *Alternaria alternate* (30.38, 32.34, 30.38) and *Botrytis cinerea* (27.44, 32.34, 30.38) respectively.

(Table 5) Data in (Table 6) showed that, hot water treatments lowered the loss in fresh weight of fruits hybrids after 3 weeks of storage compared to the control

Table 3: Effect of dipping non -inoculated and artificially inoculated tomato fruits with *A. alternata, B. cinerea* and *G .candidum* in different degree of hot water on severity of infection and decay percentage. *A = Alternaria alternata* B = *Botrytis cinerea* G= *Geotrichum candidum*

Hot water (^{0}C)	Dipping time (min)	% Severity of infection											
		Artificially inoculated by									Natural		
		A. alternata			*B. cinerea*			*G .candidum*					
		Hybrid											
		5047	935	55	5047	935	55	5047	935	55	5047	935	55
45	3	25.9	23.2	24.1	30.6	25.9	27.8	17.6	15.7	16.7	0.0	0.0	0.0
	5	22.2	18.5	20.4	27.8	25.9	27.8	15.7	0.0	0.0	0.0	0.0	0.0
	7	17.6	15.7	16.7	27.8	0.0	25.9	13.9	0.0	11.1	0.0	0.0	0.0
50	3	22.2	18.5	20.4	27.8	25.9	26.9	11.1	9.3	10.2	0.0	0.0	0.0
	5	18.5	0.0	15.7	25.9	0.0	24.1	2.8	2.8	2.8	0.0	0.0	0.0
	7	14.8	11.1	13.9	22.2	20.4	21.3	7.4	5.6	7.4	0.0	0.0	0.0
55	3	12.0	0.0	10.2	20.4	17.6	17.6	7.4	5.6	6.5	0.0	0.0	0.0
	5	10.2	8.3	9.3	17.6	15.7	15.7	7.4	4.6	5.6	0.0	0.0	0.0
	7	9.3	7.4	8.3	7.4	0.0	5.6	0.0	0.0	0.0	0.0	0.0	0.0
Control		80.6	70.4	75.92	90.74	77.78	81.5	77.78	60.19	70.4	10.19	5.56	7.41
L.S.D at 0.05%	Hot water (H)	2.37	2.25	2.69	3.21	2.92	2.83	1.61	2.67	2.39	2.10	0.82	0.84
	Time(T)	2.72	2.57	3.12	3.50	3.50	3.27	1.87	3.06	2.77	2.42	0.96	0.96
	H X T	4.73	4.38	5.26	6.42	5.87	5.66	3.24	5.31	4.79	4.20	1.66	1.69

Table 4: Effect of hot water treatments on percentage of Total soluble solids (TSS), during 3 weeks storage at 13 ºC on tomato fruits under natural and artificial inoculation with *A. alternate* (A), *B. cinerea* (B) and *G. candidum* (G).

Hot water (^{0}C)	Dipping time (min)	Total soluble solids (TSS) Brix											
		Artificially inoculated by									Natural		
		A. alternata			*B. cinerea*			*G .candidum*					
		Hybrid											
		5047	935	55	5047	935	55	5047	935	55	5047	935	55
45	3	3.5	4.2	3.9	4.0	4.7	4.4	3.8	4.5	4.3	4.2	5.0	4.9
	5	3.2	4.4	3.9	3.3	4.9	4.2	3.2	4.5	4.0	4.5	4.8	4.6
	7	3.2	4.4	4.0	4.6	5.0	4.5	4.3	4.7	4.8	4.8	5.0	5.3
50	3	3.0	3.8	4.2	3.5	5.2	4.7	3.4	4.9	4.0	4.3	5.8	5.3
	5	3.3	4.1	4.1	3.2	5.2	4.7	3.4	5.1	4.5	5.9	6.0	6.2
	7	3.1	4.4	4.1	3.6	5.5	4.9	3.5	5.4	4.5	6.3	6.4	6.2
55	3	3.8	5.5	5.1	3.9	5.7	5.8	3.8	5.6	5.7	5.0	6.8	6.6
	5	4.5	5.7	5.5	4.8	5.9	5.8	4.0	5.8	5.5	6.0	6.8	6.5
	7	5.0	5.8	5.6	5.5	6.2	5.9	5.4	6.0	5.8	6.4	6.8	6.6
Control		2.3	3.3	3.1	2.5	3.7	3.4	2.5	3.6	3.3	3.5	4.1	4.0

Table 5: Effect of hot water treatments on firmness of tomato fruits during 3 weeks storage at 13 ºC under natural and artificial inoculation with. *A. alternata* (A), *B. cinerea* (B) and *G. candidum* (G).

Hot water (^{0}C)	Dipping time (min)	Firmness											
		Artificially inoculated by									Natural		
		A. alternata			*B. cinerea*			*G.candidum*					
		Hybrid											
		5047	935	55	5047	935	55	5047	935	55	5047	935	55
45	3	30.38	32.34	30.38	27.44	32.34	30.38	30.38	34.3	32.34	32.34	35.28	33.32
	5	27.44	32.34	27.44	28.42	31.36	30.38	27.44	32.34	32.34	30.38	34.3	33.32
	7	25.48	26.46	32.34	27.44	30.83	26.46	26.46	32.34	32.34	27.44	33.32	33.32
50	3	20.58	24.5	22.54	16.66	20.58	19.6	22.54	25.48	24.5	24.5	27.44	27.44
	5	19.6	22.54	24.5	16.66	17.64	19.6	22.54	24.5	24.5	25.48	25.48	26.46
	7	16.66	22.54	20.58	15.7	19.6	17.64	22.54	20.58	22.54	23.52	25.48	24.5
55	3	14.7	15.7	15.7	12.74	14.7	14.7	14.7	17.64	16.66	22.54	23.52	22.54
	5	10.78	12.74	11.76	9.8	11.76	10.78	15.7	17.64	16.66	19.6	22.54	20.58
	7	9.8	11.76	10.78	9.8	10.78	9.8	14.7	15.7	15.7	19.6	21.56	20.58
Control		3.92	5.88	4.9	2.94	4.9	3.92	4.9	6.86	4.9	5.88	7.84	6.86

Table 6: Effect of dip in hot water on weight loss of tomato fruits after storage at 13 ºC for3weeks under natural and artificial inoculation with *A. alternata* (A),*B. cinerea* (B) and *G. candidum.*

Hot water (^{0}C)	Dipping time (min)	Weight loss (gm)											
		Artificially inoculated by									Natural		
		A. alternata			*B. cinerea*			*G.candidum*					
		Hybrid											
		5047	935	55	5047	935	55	5047	935	55	5047	935	55
45	3	0.9	0.14	0.87	1.82	0.8	1.12	0.42	0.14	0.25	0.29	0.11	0.15
	5	2.0	1.4	1.8	2.4	1.5	2.1	0.88	0.3	0.6	0.96	0.2	0.3
	7	2.5	2.2	2.2	3.7	2.52	3.5	1.9	1.2	1.94	1.5	1.14	1.9
50	3	3.8	3.18	4.5	4.3	3.6	4.3	2.6	2.3	3.01	2.9	1.7	2.9
	5	4.3	6.42	6.13	6.1	6.66	6.4	4.12	2.6	3.6	3.8	3.8	3.44
	7	5.6	5.0	7.31	6.1	5.04	6.9	6.13	6.46	6.48	4.9	3.8	5.9
55	3	7.9	5.47	7.4	8.9	5.96	8.34	6.4	5.1	6.66	6.4	5.06	6.2
	5	7.9	6.42	8.8	8.9	6.9	9.9	7.5	7.76	7.3	6.7	4.8	6.6
	7	8.9	6.94	8.8	8.9	7.76	8.34	7.8	5.76	7.66	6.9	5.06	6.2
Control		10.6	8.06	10.2	11.9	8.4	11.7	8.7	5.9	8.04	7.9	5.67	7.9

in naturally and artificially inoculated with *A. alternata, B. cinerea and G. candidum*. Hot water treatments 45ºC/3 min showed the lowest loss in tomato fresh weight in hybrid 935(0.14, 0.8, 0.14), hybrid 55 (0.87, 1.12, 0.25) and hybrid 5047(0.9, 1.82, 0.42) respectively. *Geotrichum candidum* (0.42, 0.14, 0.25) showed the least decrease on the weight loss of the three tomato fruit hybrids and followed by *Alternaria alternata* (0.9, 0.14, 0.87) and *Botrytis cinerea* (1.82, 0.8, 1.12) respectively.

Discussion

In our work we used hot water as a safe method, 55^{0}C/7 min significantly suppressed the decay on naturally infected tomato fruits as well as on the artificially inoculated fruits with *G. candidum, B. cinerea* and *A. alternata* pre cold storage at 13^{0}C for 3 weeks with 935, 55 and 5047 tomato hybrids respectively. On the other hand, hot water treatment showed good Quality parameters in decreasing of weight loss and increasing of firmness and TSS with 45, 50 and 55 for 3, 5 and 7 min.

In our work, the isolated fungi are *Geotrichum candidum*, *Botrytis cinerea*, *A. alternata, Aspergillus niger, Fusarium* sp and *Epicoccum sp.* This agree with (Ragab *et al*., 2001); (Zhao *et al.,* 2007) who showed that under inappropriate conditions fruits are subjected to be attacked by several microorganisms such as *Alternaria alternata*, *Botrytis cinerea*, *Aspergillus niger* and *Fusarium* spp. that have been found associated with tomato fruit rots. Andrés *et al.,* (2006) isolated *Fusarium solani* f. sp. *phaseoli*, *Rhizoctonia solani*, *Pythium ultimum*, *Pythium* spp, *Fusarium avenaceum*,

F. culmorum, *Botrytis cinerea*, *Sclerotinia sclerotiorum* and *Sclerotium rolfsii* from 419 beans (*Phaseolus vulgaris* L.). Abd-Alla *et al*., (2007) isolated *Geotrichum candidum* from lemon fruits. Mahovic and Bartz (2004) indicated that *Geotrichum candidum* causes some diseases in tomato fruits.

Ahmed (2010) isolated six different genera of fungi *i.e., Alternaria* spp*., Botrytis cinerea, Fusarium* spp. *Mucor* sp, *Penecillium* spp. and *Sclerotinia sclerotiorum* from beans cultivated in different locations in Egypt. *S. sclerotiorum* and *B. Cinerea* were the most dominant fungi. Fahiem (2010) isolated seven fungi genera *i.e*., *Alternaria spp., Botrytis cinerea, Fusarium* sp*., Mucor* sp*., Pythium aphanidermatum, Rhizoctonia solani* and *Sclerotinia sclerotiorum* from naturally infected snap bean pods collected from different Egyptian Governorates and found that these genera were able to infect the wounded and un-wounded bean pods of cv. Paulista.

Reduction on the mycelia growth or decay incidence might be attributed to the direct effect of heat on the spore germination as well as mycelial growth resulting in slowing growth rate of fungus on the infected fruits as reported by lopez-carbera *et al.,* (1998).

Li-Cohen and Bruhn (2002) discovered species of fungi associated with tomatoes including *Aspergillus*, *Fusarium, Penicillium* and *Rhizopus*. The isolation of *Aspergillus niger, Rhizopus stolonifer, Mucor* species from rotten tomato confirmed the studies of Chuku *et al.,* (2008) and Akinmusire (2011) who reported that *A. flavus* and *A. fumigatus* caused tomato spoilage. Spores of *Verticillium sp* and *Botrytis cinerea* are air-borne and may be endemic to the area that this research was conducted. *Aspergillus niger, Aspergillus flavus, Alternaria alternata, Alternaria solani,* and *Fusarium oxysporium* are responsible for the storage decay of tomato fruits in Nigeria. These Fungi that cause deterioration are well known and have been reported in some countries of the world (Mahovic and Bartz, 2004).

Rodov *et al.,* (2000) stated that hot water dips at 52ºC for 2 min controlled the development of the postharvest pathogens infected Oroblanco fruits. Apelbaum *et al.,* (1981) found that the lower ethylene production in response to heat treatment may be due to induced changes in cellular membrane. These changes may inhibit membrane associated oxidation of Acc(1-aminocyclopropane-1-carboxylic) to ethylene. Biggs *et al.,* (1988) used mature green intact tomatoes found lower ethylene production and respiration rate after heat treatment and shown that high temperature stress had marked yet differential effect on Acc synthase and Acc oxidase which inhibit conversion of Acc to ethylene in addition, heat-shock has been shown to block normal protein synthesis or to shift synthesis toward heat-shock proteins (Vierling, 1991 and Saltveit, 2000). These new protein groups confer thermo tolerance in tissue.

Barkai-Golan (1973) reported that hot water dips at 39ºC-52ºC for 5-10 min., in vitro and in vivo inhibited spore germination of postharvest fungi and decay development in tomato fruits.

Total soluble solids (TSS) is an indirect indication of the level of soluble sugars and therefore sweetness (Saltviet, 2005). Khazaei *et al.,* (2008) reported that drying of tomato slices caused an increase in soluble solids and acidity. The type and extent of the effects of drying tomato on quality characteristics are dependent on the methods of drying (heat source, amount and duration of temperature and final moisture content of the product), the pre-treatment procedures and the cultivars (Zanoni *et al.,* 1999); (Kerkhofs *et al.,* 2005); (Chang *et al.,* 2006); (Latapi and Barrett 2006a, b); (Heredia *et al.,* 2007). The decrease in moisture content in the fruits is usually accompanied by an increased percentage of TSS, since TSS is the major component of dry matter (Malundo *et al.,* 1995). Thus, the value of TSS significantly (PB0.0001) increased after drying.

In our work, hot water treatments increased total soluble solids in naturally and artificially inoculated with *A. alternata, B. cinerea and G. candidum* in Tomato fruits hybrids than control. This agrees with Amin *et al*., (2013) in their work on two different varieties of banana, 'Bari Kola' and 'Sabri Cola' treated with six different combinations of hot water temperatures and times. The bananas treated with combinations of 53ºC for 9 min or 55ºC for 7 min obtained higher TSS, total sugars than untreated fruits.

Firmness is a vital determinant in assessing the degree of ripening (Arzate- Vazquez *et al.,* 2011). The decrease in fruit firmness may be due to gradual breakdown of protopectin to lower molecular weight fractions which are more soluble in water and this is directly correlated with the rate of softening of the fruits (Wills *et al.,* 1981). In our work hot water treatments increased Firmness compared to the control in naturally and artificially inoculated with *A. alternata,*

A. cinerea and G. candidum in Tomato fruits hybrids. This agrees with Mizrach and Flitsanov (1999) who reported that tomato treated with hot water had higher firmness at 42ºC than untreated controls. This may be because of inhibition or inactivation of cell wall hydrolytic enzymes such as polygalacturonase and pectin

esterase or suppression of mRNAs synthesis coding for wall softening enzymes in tomatoes (Paull and Chen, 2000); (Safdar khan, 2009). The firmness of tomato fruits increased in treated stored fruits during storage for 3 weeks compared to untreated (control) that agrees with (Safdar khan, 2009). Application of hot water at 50ºC for 10 min. 'Gros Michel' fruit caused a delay in degreening and maintained higher pulp ûrmness compared to untreated fruit (Ummarat *et al.,* 2011). The treatment increased free phenolics and ûavonoids during storage and also (Li *et al.,* 2013) associated images obtained with scanning electron microscopy with the postharvest quality of different apple cultivars after applying forced-air heat at 45 to 60ºC for 3 h. 'Red Fuji' apples subjected to heat at 45ºC maintained the highest total phenolics content and antioxidant capacity, while 'Golden Delicious' apples were more sensitive to heat treatment based on their loss of TA. These differences in quality were related to changes in the microstructure of heated fruit and heat treatment effects on sensory traits can also be temporary, as demonstrated by (Jemric and Fruk, 2013), who presented an exhaustive analysis of 'Venus' nectarines treated with hot water immersion at 48ºC for 6-12 min followed by storage at 0ºC for 2 weeks. After 2 weeks, nectarines heated for 12 min achieved better sensory scores for ûrmness, texture, sugar/acidity ratio, aroma, taste and general appearance.

Postharvest treatments decrease respiration through inhibition of ethylene biosynthesis or action (Srivastava and Dwivedi, 2000). Naffa *et al*., (2003) reported that hot water treatment at 45^0C for 5 min reduced the weight loss of green onion plants either naturally infected or artificially inoculated with *Botrytis alli* during the cold storage for 4 weeks. The weight loss occurs during storage due to its respiration process, the transference of humidity and some process of oxidation (Ayranci *et al.,* 2003). However, the all treatments significantly reduced the weight loss of tomatoes during storage. The loss of fresh appearance in hot water treatment fruit was ascribed to the high level of water loss, the respiration rate and fruit weight losses by closing stoma (Zheng and Zhang, 2004). Also Schirra (2011) found that the loss of fresh appearance in hot water treatment fruit was ascribed to the high level of water loss. The hot water treatment should be used as good tool for preservation of tomato fruits with high quality.

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