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Effect of Hot Water Alone or in Combination with Acetic Acid on Control of Blue Mold Disease and Fruit Quality of Pears During Storage

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Abstract *Penicillium expansum* is the main postharvest fungi of pear cv. 'Le-cont' causing serious economic losses during domestic markets and storage. Two substitutes of synthetic postharvest fungicides, hot water alone and the combined treatments of hot water and acetic acid solution were tested at different temperatures, concentrations and immersion time. Experiments were carried out *in vitro* to evaluate mycelial growth and spore germination and investigate the combined effects of hot water with acetic acid treatments on controlling blue mold disease and maintaining postharvest quality of pear fruit *in vivo* test. Storage period was of 42days at 5^{o}C and plus 7 days at 20^{o}C as a simulated marketing period (shelf – life). In *vitro* trails, mycelial growth and spore germination *in vitro* was inversely related to the period of immersion, to the range of temperature and to the concentration of acetic acid used. A complete reduction of mycelial growth and spore germination of *P.expansum* occurred after a 8 min immersion period to 5% acetic acid solution at 58^{0}C.Spores treated with immersion in other combination of hot water and acetic acid treatments gave a strongly reduction of the mycelial growth and spore germination than hot water alone treatments.In *vivo* trials ,immersion of pear fruit inoculated with spores of *P.expansum* in water at 52 or 56°C for 4 or 8 min significantly reduced blue mold development compared with fruits treated with water at 27°C for 8 min (control).Immersion inoculated pear fruits in 5% acetic acid solution at 56^{o}C for 8 min gave a completely reduction of the percentage of disease incidence and lesion diameter of blue mold disease of pears, meanwhile, fruit treated with immersion in other combination of hot water and acetic acid treatments gave a strongly reduction of blue mold development. At 48^{o}C for 4 min treatment alone gave less effect for reducing the percentage of disease incidence and lesion diameter. The addition acetic acid solutions to hot water significantly improved control of blue mold compared to hot water alone. Both hot wateralone and the combined treatments of hot water and acetic acid showed no significantly increasedonthe firmness and total soluble solids contentand decreased titratable acidity.
Overall, the combination of hot water and acetic acid solution treatments had a pronounced effect on reducing blue mold development and maintaining quality of pear fruit. These treatments may extend the storage life by preventing both pathological and physiological disorders

Keywords: Postharvest-*Penicilliumexpansum* (Link) Thom -Blue mold-Pear- Hot water Acetic acid solution- Control

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Introduction

Blue mold caused by *Penicillium expansum* (Link) Thom is one of the most important postharvest diseases of pear fruit that often causes extensive losses during storage and transportation (Zhang *et al*., 2006).*Penicillium expansum*i sphytopathogenic fungus that causes fruit losses ranging from 5% to 20% in world (Cappellini and Ceponis, 1984) and up to 50% in developing countries (El-Ghaouth, 1997).Using of chemical fungicides gave satisfactory control against mould infection, but has residual harmful effect to human and environment (Eckert, 1990). Moreover, successive use of fungicides could lead to develop some significant fungal isolates resistant to used fungicides. Therefore, alternative fungicide treatments are needed for the management of postharvest diseases of fruits (Abd-El-Latif, Faten and Abd-El-Kareem, 2009).

Hot water treatment alone has been shown to be an effective physical method for the control of a wide range of pathogens for storage rots (Palou *et al*., 2001; Schirra *et al*., 2000; Teitel *et al*., 1989). Besides reduction of storage decay, dipping fresh produce in hot water is believed to improve the quality of fruit for prolonged storage (Ben-Yehoshua, 2003; Fallik, 2004). A heat shock host response from hot water treatment has been found to weaken fungal growth by inducing host antifungal compounds involved in resistance (Fallik *et al*., 1996).Pre–storage hot water dips of fruit at temperatures above 40ºC have been shown to be effective in controlling storage decay, not only by reducing the pathogen but also by enhancing the resistance of fruit tissue, influencing host metabolism and ripening (Barkai-Golan and Philips, 1991).More importantly the practice of hot water washing of fresh produce is environmentally friendly and involves no risk to health. The practice of hot water treatment would reduce production costs and would cost less for the consumers (Lurie, 1998).

Acetic acid is a proven antimicrobial agent and a natural and safe food ingredient (Radi *et al*., 2010), also it is a valid candidate and effective in preventing postharvest fruit decay caused by *P. digitatum* and *P. italicum*. Studies have been conducted on citrus fruit such as oranges, lemons and grapefruit (Sholberg and Gaunce; 1995, Sholberg, 1998). Acetic acid or vinegar vapor was effective in preventing germination of conidia of brown rot, grey mould and blue mould and subsequent decay of stone fruit, strawberries and apples (Sholberg *et al*., 2000).

Use of treatments where hot water and acetic acid are combined, so as to reduce both the acetic acid concentrations and water temperatures, deserves evaluation because this approach could conceivably reduce safety issues, improve the efficacy of the treatment compared with either acetic acid or hot water alone, and minimize injuries to the treated products. The synergistic effect of hot water treatment combined with low acetic acid

concentrations to control the postharvest decay of apple fruit (Radi *et al.*, 2010) has been demonstrated.

The aim of this experiment was to evaluate the antifungal properties of hot water alone or in combination with acetic acid treatments *in vitro* test and to investigate the effects of immersion in these treatments on controlling blue mold disease and maintaining postharvest quality of pear fruit cv. "Le-cont" *in vivo* trials.

Materials and methods

This study was conducted In Plant Pathology Laboratory of the Department of Agricultural Botany, Faculty of Agriculture, Fayoum University, Egypt to study the effect of a hot water alone or in combination with acetic acid on linear growth and spore germination of *Penicillium expansumin invitro* as well as on controlling blue mold decay of pear fruits and its effects on quality of pear after storage *in vivo*.

Source of Pear fruit

The mature Pear (*Pyrus pyrifolia* Nakai.) cultivar "Le-cont" fruits used in the experiment were grown in a private orchard (Aboksah), Fayoum Governorate, and brought to the laboratory immediately after harvest. They were selected for their uniformity, size, color and shape, and for being free of damage and fungal infection.

Inoculum preparation

A highly virulent isolate of *P. expansum* Link originally isolated from infected pear fruit was used. This isolate was grown on potato dextrose agar (PDA) at 25ºC for 7 days. Spores were harvested by adding 5 ml of sterile distilled water containing 0.1% (v/v) of Tween 20to the Petri dish, rubbing the surface with a bacteriological loop, and filtered through two layers of cheesecloth. The spore concentration was determined with a haemacytometer and adjusted to 10^{6} spores ml^{-1} with sterile distilled water.

Effect of hot water alone or in combined with acetic acid on linear growth and spore germination of Penicillium expansum in vitro

To determine the influence treatment combing hot water and acetic acid concentration and the time of treatment on mycelial growth and spore germination of *P. expansum* one ml spore suspension of 10^{5} of the pure culture of *P. expansum* was put onto sterilized glass tubes containing 9 ml of distilled water or acetic acid at concentration 2.5 and 5% were placed in the circulating water bath at 48, 52 and 56°C for 4, 8 min. After treatments,

the glass tubes were immersed in the water bath at 20°C for 10 min to allow the heat to redistribute and to equilibrate at room temperature. Glass tube immersed in a circulatory water bath at 27°C for 8min served as control. 5ml of the spore of suspension of each treatment was inoculated in the middle of petri plates containing PDA and incubated at 25°C to evaluate radial mycelial growth and spore germination. After 72 h incubation, the fungal mycelial growth was measured. Five plates per treatment were used to evaluated mycelial growth whilst, for germination, spores were removed from the surface of the cultures with a steril bacteriological loop in 5ml of sterile distilled water. Suspensions were filtrated with sterile filter paper (watman) No.1 to remove fungal mycelia and were diluted to concentration of 10^5 fungal spore/mlsuspensions.Germination percentage of spore was determined by counting 100 spores three times in each drop microscopically (Martínez *et al*., 2012). The experimental design was a completely randomized block with and repeated twice.

Reduction% of mycelial growth was calculated as follows: [(mycelial growth(control) - mycelial growth (treatment) / control mycelial growth] x 100.

Reduction% of germinated conidia = {[germinated conidia (control) – germinated conidia (treatment)] / germinated conidia (control)} x 100.

Effect of hot water alone or in combination with acetic acid on blue mold development of pear fruitsin vivo

Healthy pear fruits were surface sterilized by dipping them into 1L (V: V) 2% sodium hypochlorite for 2min at room temperature. Fruits were rinsed twice with sterile distilled water and allowed to dry on sterile filter paper. The fruits were wounded (5mm diameter and 3mm deep approximately) using a sterile cork-borer. Each wound site was inoculated with 40µl of spore suspension 10^5 spores/ml) of *P. expansum*. Before the treatment application, inoculated fruits were left at ambient temperature for 24h.Inoculated fruits were immersed in a circulating water bath at 52 or 56°Cfor 4 and 8min and in hot water at 52 or 56°C plus 2.5 and 5% acetic acid solution for 4 and 8 min. Inoculated fruits were immersed in cold water (27°C) for 8 min served as control. After treatment applications, fruits were allowed to dry for about 6h at room temperature and stored in perforated carton box with dimension 45x35x10cm at 5°C for 42 daysin 85 - 90%RH followed at 20°C for 7 days to simulate marketing life and normal shelf-life conditions. At end of the storage period, disease development was evaluatedas percentage disease incidence and by measuring the mean lesion diameter (mm)of inoculation sites per fruit for all treatments. The experiment was carried out two times.

Effect of hot water alone or in combination with acetic acid quality of pear fruitsin vivo

To evaluate the effect of hot water treatments alone or in combination with acetic acid solutions on postharvest quality of pear fruits, harvested fruits were treated, and then stored as described above (42 days at 5°C of cold storage and additional 7 days at 20°C).Firmness values of each fruit were measured with the help of penetrometer (EFFIGI, 11MM Prob) for five fruits per treatment as described by Pocharski *et al*., (2000)**.** Total soluble solids (TSS) and Total titratable acidity (TTA) were assessed in juice obtained from five fruits per replicate. TSS content was determined with a hand refractometer (Kernco, Instruments Co. Taxas), Total titratable acidity (TTA) was estimated as percent malic acid by titrimetric method with 0.1 N sodium hydroxide on 5 ml of fruit juice using phenolphthalein as an indicatoraccording to A.O.A.C., 1990. There were three replicates of 10 fruit each per treatment with complete randomization.The experiment was repeated twice.

Statistical Analysis

Effects of treatments were analyzed by ANOVA and significance of differences among means was tested applying the LSD test at the 5 % level of probabilityaccording to Steel *et al*. (1997) using the SAS Statistical package ver. 9.00 (SAS Institute, Cary, USA).

Results and discussion

Effect of hot water alone or in combination with acetic acid on linear growth and spore germination of Penicillium expansum in vitro

The effects of three of hot water treatments i.e. 48, 52 and 56°C, two concentration of acetic acid i.e. 2.5 and 5% were added to hot water at 48, 52 and 56° for 4, 8 min were studied*in vitro*.Cold water (27°C) for 8 min was as control treatment.

Results in Table (1 and 2) indicate that all treatments have inhibitor effect on the growth and decreased the percentage of spore germination of fungus tested. Their effects increased with increasingwatertemperatures,acetic acid concentrations and immersion times.A hot water treatment of 56 °C for 8 min resulted showed highly effect to reducing mycelial growth (74.22%), followed by 56 °C for 4 min treatment it gave71.78% reduction in the mycelial growth compared with other hot water treatment alone. Similarly, these treatments, *P. expansum* spores immersed in hot water at 56 °C for 8 min showed highly effect to reducing percentage of spore germination(56.52%), followed by 56 °C for 4

min treatment it gave 45.87 % reduction in percentage of spore germination compared with other hot water treatments alone.

Addition of acetic acid to hot water significantly reduced the mycelial growthand spore germination of *P. expansum* compared with hot water treatments alone and control treatment. Complete reduction in linear growth and spore germination of *P. expansum* was obtained with immersion of fungusspores in 5% acetic acid solution at 56^{o}C for 8 min, while control treatment showed 100% of mycelail growth. Spores treated with immersion in other combination of hot water and acetic acid treatments gave a strongly reduction of the mycelial growth and spore germination than hot water alone treatments.

Table 1. Effect of hot water alone or in combination with acetic acid on linear growth of *Penicillium expansumin vitro.*

Treatment			Mycelial growth (mm)*	Reduction** (%)
Hot water ^{o}C	**Acetic acid Conc.% (v/v)Immersion time(min)**	**Immersion time(min)**		
27	0	8	90.0 a	_
48	0	4	49.8 b	**44.67**
48	0	8	47.8 b	**46.89**
52	0	4	45.4 c	**49.56**
52	0	8	43.2 d	**38.00**
56	0	4	25.4 e	**71.78**
56	0	8	23.2 f	**74.22**
52	2.5	4	19.7 g	**78.11**
52	2.5	8	18.7 gh	**79.22**
52	5	4	17.4 h	**80.67**
52	5	8	13.8 i	**84.67**
56	2.5	4	12.9 j	**85.67**
56	2.5	8	12.0 j	**86.67**
56	5	4	6.5 k	**92.78**
56	5	8	0.0 m	**100.00**

* Means followed by the same letter are not significantly different according to LSD test, p≤0.05. Mean are for two trials. ******reduction in fungal growth at different treatments, calculated relatively to its growth in control

Table 2. Effect of hot water alone or in combination with acetic acid on spore germination of *Penicillium expansumin vitro.*

Treatment			spore germination%*	Reduction** (%)
Hot water°C	Acetic acid Conc.% (v/v)	Immersion time(min)		
27	0	8	92.00 a	_
48	0	4	65.38 b	**28.94**
48	0	8	60.11 c	**34.66**
52	0	4	58.60 d	**36.30**
52	0	8	56.33 d	**38.77**
56	0	4	49.80 e	**45.87**
56	0	8	40.00 f	**56.52**
52	2.5	4	38.82 f	**57.80**
52	2.5	8	31.36 g	**65.91**
52	5	4	23.60 h	**74.38**
52	5	8	14.85 i	**83.86**
56	2.5	4	1o.50 j	**88.59**
56	2.5	8	8.50 j	**90.76**
56	5	4	3.50 k	**96.20**
56	5	8	0.00 l	**100.00**

*Means followed by the same letter are not significantly different according to LSD test, $p \leq 0.05$. Mean are for two trials. ******reduction in spore germination at different treatments, calculated relatively to itsspore germination in control.

These results are in agreement with previous investigations. Tohamy *et al.* (2004) examined *in vitro* effect of hot water treatment on fungi. A linear growth of Botrytis and Alternaria was obtained from standardized number of spore treatment at 45 and 50 °C for different periods and was inversely related to the temperature treatments and time of dipping. Therefore, all these reports of studies agreed with the results of this trial. Antifungal activities of acetic acid were reported in previously research .Radi *et al.* (2010) showed that treatment with acetic acid at 50°C can significantly reduce the growth of *P. expansum* spores .Chen *et al*. (2004)

indicated that acetic acid at concentrations of 2–5% and at ambient temperatures for 5 min could be an effective chemical for prevention of growth of *P. expansum* in apples.

Effect of addition acetic acid to hot water on blue mold development and fruit quality of pears in vivo

Pear fruits cv. "Le-cont" artificially inoculated with *P.expansum* were immersed in hot water alone treatments at 52 or 56°C for 4 and 8 min and in hot water at 52 or 56°C plus 2.5 and 2.5 or 5% acetic acid solution for 4 and 8 min for controlling blue mould disease of pear fruits and to investigate their effects on quality of pears after storage. *In vivo* test, all hot water treatments alone significantly reduced the blue mould as disease incidence or lesion diameter of pear fruits as compared with treated fruits with water at 27°C for 8min (cold water). As the dipping time increased from 4 min to 8 min, a greater degree of disease control was observed for each hot water treatment (Table 3).

The greatest reduction of blue mold in pear fruits occurred at 56°C when dipped for 4 min or 8 min which reduced disease incidence or lesion diameter more than 50.39 and 58.82%, respectively. Control of blue mold disease of pear fruits inoculated with spores of *P.expansum* before immersion for 4, 8 min in hot water alone at 48, 52 and 56°C, was improved significantly by the addition of acetic acid to the water, increasing the solution temperature or prolonging the immersion period. Immersion for 4 or 8 min in 5% acetic acid at 52 or 56 ◦C was significantly better than water alone at these temperatures.

Fruit inoculated with *P. expansum* and treated with Immersion in 5% acetic acid solution at 56^{o}C for 8 min gave a completely reduction of the percentage of disease incidence and lesion diameter of blue mold decay of pears, meanwhile, fruit treated with Immersion in 5% acetic acid solution at 56^{o}C for 4 min gave a strongly reduction of the percentage of disease incidence and lesion diameter of blue mold decay of pears by 96.00 % and 90.98%, respectively, followed by fruit treated with 2.5% acetic acid solution at 56^{o}C for 8 reduction of disease incidence and lesion diameter. At 48^{o}C for 4 min treatment alone resulting less effect for reducing the percentage of disease incidence and lesion diameter by 59.00 % and 34.90%, respectively.

Table 3. Effect of dipping pear fruits in hot water alone or in combination with acetic acid on blue mold development on artificially inoculated pear fruits with *P.expansum* after storage at 5°C for 42 days and plus 7 days at 20°C.

Treatment condition	blue mold development			
	Incidence %	Reduction (%)**	Lesion diameter (mm)	Reduction (%)**
Single treatment				
Control (water at 27°C for 8min)	100.0 a	_	25.5 a	_
Hot water at 52°C for 4 min	41.0 b	59.00	16.6 b	34.90
Hot water at 52°C for 8 min	41.2 b	58.80	14.4 c	43.29
Hot water at 56°C for 4 min	38.8 c	61.20	12.4 d	50.39
Hot water at 56°C for 8 min	30.4 d	61.60	10.5 e	58.82
Combined treatment				
Hot water at 52°C + 2.5 % acetic acid for 4 min	27.4 e	72,60	9.4 f	63.14
Hot water at 52°C + 2.5% acetic acid for 8 min	26.1 e	73.90	8.5 f	66.67
Hot water at 52°C + 5% acetic acid for 4 min	18.0 f	82.00	6.5 g	74.51
Hot water at 52°C + 5 % acetic acid for 8 min	15.5 g	85.5	5.3 h	79.22
Hot water at 56°C + 2.5 %acetic acid for 4 min	7.0 h	93.00	3.4 j	86.67
Hot water at 56°C + 2.5 %acetic acid for 8 min	4.8 j	95.20	3.0 j	88.24
Hot water at 56°C +5 % acetic acid for 4 min	4.0 j	96.00	2.3 j	90.98
Hot water at 56°C + 5 % acetic acid for 8 min	0.0k	100.00	0.0 k	100.00

*Means followed by the same letter are not significantly different according to LSD test, p≤0.05. Mean are for two trials. **reduction indisease incidence or lesion diameter at different treatments, calculated relatively to itsdisease incidence or lesion diameter in control.

The effect of heating on the decay of apples caused by *P.expansum* may not only be the result of direct inhibition of fungal germination and growth by high temperature, but may also partly due to the formation of an inhibitory substance in the heated peel (Fallik*et al*., 1995) or due to activation of two major proteins which may induce resistance in fruits Sabehat *et al*., 1995or due to the melting of wax layer which fills the small cracks, as suggested by Roy *et al*. (1994) for heated Golden Delicious apples.Other potential effects of hot water include induction of antifungal-like substances that inhibit fungal development in fruit tissue, induction of proteins such as chitinase and β-1,3-glucanase, stabilisation of membranes,

inhibition of synthesis of cell wall hydrolytic enzymes (polygalacturonases), and delay of degradation of pre-formed antifungal compounds that are present in unripe fruit (Schirra *et al*., 2000).Also, who mentioned that Heat treatment has been reported to induce many plant-defense mechanisms such as accumulation of phytoalexins, pathogenesis- related proteins, and lignin-like materials, causing the treated fruit to become more resistant to subsequent infections. In recent years, several other workers including Inkhaand Boonyakiat (2010); Jabar *et al.* (2011) and Singh *et al*., (2015) have also used heat treatment with success in reducing post- harvest decay of other fruits.

These results partially contradict with those of of Archbold*et al*., (1997) who mentioned that the efficacy of acetic acid might be due to its volatile compounds which show promising results as a post-harvest fumigants for controlling Botrytis on strawberry fruits. Acetic acid vapors were more effective for controlling postharvest decay, the mechanisms of acetic acid inhibition for microorganisms apparently that it may affect the cell membrane interfering with the transport of metabolites and maintenance of membrane potential (Sholberg *et al.*, 1998). Also, the undissociated part from the acid was primarily responsible for its antimicrobial activity where it can penetrate the microbial cell and exert its toxic effect (Banwart, 1981). Moreover, Morsy *et al.* (1999) obtained a complete inhibition using acetic acid solutions for controlling *B. cinerea* and *Rhizopus stolonifer*. Where, acetic acid vapors reduced disease incidence by 80.1 and 77.2% for *B. cinerea* and 83.0 and 75.7% for *R. stolonifer*. Helal *et al.,* (2003) found that acetic acid at conc. 1.75 m/l completely inhibit growth of black mold *Alternaria alternata* and gray mold *Botrytis cinerea*. Also, dipping artificially inoculated tomato fruits in 4% acetic acid soluation for 30 min and storing at 13C for 16 days inhibited tomato fruit rots caused by the two pathogens. Tohamy *et al.* (2004) stated that, acetic acid was more effective in controlling postharvest decay of tomato fruits caused by *Alternaria alternata* and gray mold *Botrytis cinerea* than other chemical treatments.

In our work, the application of hot water combined with acetic acid solution treatments showed beneficial effect on control of blue mold disease in pear fruit could be attributed to different causes. A direct detrimental effect of the hot water and acetic acid solution on the fungus present on the fruit surface is possible, an indirect effect by inducing defense mechanisms in the fruit tissue. Synergistic effects of heat and acetic acid solutions to control *Penicillium* decay on citrus fruit were also observed in previous research (Smilanick *et al*., 1997). The addition of ethanol to water reduces its surface tension and facilitates better contact and penetration of the solution to the parts of the berry where pathogen resides. In addition to enhanced toxicity to *P. expansum*, heat increased the amount of acetic acid that penetrated into the fruits.

With regard to the fruit quality characteristics, the data of (Table 4)shows that there were no significant differences in firmness, total soluble solids (TSS) (%) and titratable acidity (TA) % among pear fruits treated with immersion (dipped) in water at 52 or 56°C for 4 and 8 min and in hot water at 52 or 56°C plus 2.5 and 5% acetic acid solution for 4 and 8 min including control, fruits immersed in cold water (27°C) for 8 min after storage at for 42 days and plus 7 days at 20^{o}C .

Table 4. Effect of dipping with hot water treatment alone or in combination acetic acid solutions on quality parameters on pear fruits artificially inoculated with *P.expansum* after storage at 5^{o}C for 42 days and plus 7 days at 20^{o}C.

Treatment condition	**Firmness[a] Kg /cm^2**	**Total soluble solids (TSS) (%)**	**Titratable acidity (TA) (%)**
Single treatment			
Control (water at 27°C for 8min)	4.62a	11.53a	0.40 a
Hot water at 52°C for 4 min	4.63a	11.62a	0.34 a
Hot water at 52°C for 8 min	4.63a	11.60a	0.40 a
Hot water at 56°C for 4 min	4.67a	11.53a	0.34 a
Hot water at 56°C for 8 min	4.68a	11.55a	0.35 a
Combined treatment			
Hot water at 52°C + 2.5 %acetic acid for 4 min	4.73a	11.68a	0.36 a
Hot water at 52°C + 2.5% acetic acid for 8 min	4.80a	11.65a	0.35 a
Hot water at 52°C + 5% acetic acid for 4 min	4.70a	11.66a	0.34 a
Hot water at 52°C + 5 % acetic acid for 8 min	4.72a	11.69a	0.31 a
Hot water at 56°C + 2.5 % acetic acid for 4 min	4.81a	11.66a	0.34 a
Hot water at 56°C + 2.5 % acetic acid for 8 min	4 .83a	11.69a	0.36 a
Hot water at 56°C +5 % acetic acid for 4 min	4.79a	11.79b	0.33 a
Hot water at 56°C + 5 % acetic acid for 8 min	4.80a	11.80b	0.36 a

Means followed by the same letter are not significantly different according to LSD test, p≤0.05.

Except for the combined treatment of 5% acetic acid solution with 58°C temperature for 4 and 8 min that showed significantly higher total soluble solids (%) than the control and all other treatments. On the other hand, firmness and total soluble solids were slightly higher in fruits treated with all treatments than those treated with water at 27°C for 8 min.

The titratable acidity % of the pears treated with all hot water alone or in combination with acetic acid solution treatments were equal or lower than that of the control.The result showed that heat treatment has no significant effects on the skin firmness and total soluble solids and Titratable acidity of pear.

This result agrees with the study of Mutari and Debbie (2011) which stated that the effect of temperature on fruit firmness was not significant.Furthermore, Fallik (2004) who mentioned that there is no significant difference in the firmness of tomato at either 40 °C or 50 °C. This might be as a result of sealing the cracks or natural openings which significantly reduce water loss, and thus maintain fruit firmness after storage. Klein and Lurie (1992) reported that heated tomatoes when removed from storage showed an increase in the concentrations of soluble solids than non-heated fruit; also heated apples e.g. Golden delicious were perceived as sweeter, crisper and more acceptable to the consumer than non-heated fruit.However, the combinations tested did not show a significant improvement in fruit quality in comparison with the hot water alone treatments

Fruit quality parameters (firmness, soluble solids, total acidity. Heat treatments may affect postharvest quality in several ways. It has a direct effect on fungal growth, it may induce antifungal substances and the wax layer may melt into wounds and stomata (Schirra *et al*., 2000).

In conclusion, based on these results, it appears that the use of generally regarded as safe (GRAS) compounds, such as acetic acid solution, is a useful approach to improve the efficacy of hot water treatments used for postharvest blue mold disease control and to maintain postharvest quality for pear fruits. Our results indicated that dip treatmentsin 5% acetic acid solution at 56^{o}C for 8 min. had complete protective effect against postharvest blue mold development whilst maintaining fruit quality.

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