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# EFFECTS OF LOW TEMPERATURE STORAGE AND VAPOR HEAT TREATMENT ON THE QUALITY OF SWEET ORANGE

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## ABSTRACT

Oranges were treated with water vapor (50°C) for 0-20 minutes at 5 minutes interval and stored at 5°C for 75 days. Weight loss, Total Soluble Solids, surface pitting, TSS/Acid, disease incidence were increased, while reducing sugars, acidity and ascorbic acid were declined during storage. The highest weight loss (9.50%), Total Soluble Solids (11.10 ºBrix), surface pitting (16.40%), sugar acid ratio (7.63), disease incidence (10.53%) and the least acidity (1.41%) and ascorbic acid (29.21mg/100g) were recorded in storage for 75 days. Vapor heat treatment for 5 to 10 minutes resulted in least surface pitting (2.78%), TSS/Acid ratio (6.16), disease incidence (1.44%) and highest acidity (1.59%). But increasing VHT duration to 15-20 minutes resulted in highest weight loss (4.44%), Total Soluble Solids (10.57ºBrix), TSS/Acid ratio (7.00) disease incidence (6.33%) and surface pitting (6.78%) as well as the least ascorbic acid content (35.76mg/100g). Vapor heat treatment (5-10 minutes at 50°C) can be utilized to maintain fruit quality for longer period and minimize chilling injury in cold storage. However, extended heat treatment beyond 10 minutes resulted in moisture loss and surface pitting similar to chilling induced pitting and hence adversely affected the fruit quality.

**Key words:** Vapor Heat Treatment, Sweet Orange, Storage, Low Temperature Storage.

## INTRODUCTION

Citrus is cultivated in tropical and subtropical regions (Piccinelli *et al*. 2008). Pakistan is a major citrus producer and around 48% of citrus production is consumed at indigenous level, 10% is being exported. Two percent is processed, whereas post-harvest losses are 40% (Arif *et al*. 2013). Storage at low temperature impedes citrus fruits deterioration but extended exposure may cause chilling injury (Lafuente *et al*. 2005). Chilling injury symptoms are watery breakdown, scalding, rind pitting and sunken areas (Lafuente and Zacarías, 2006) and the affected fruits are prone to decay (Khan *et al*. 2007).Heat treatments can minimize the development of pathogen development (Lurie *et al*. 2004). Therefore, the present study was designed with the objective to assess the potential of heat treatment for inducing chilling tolerance and minimizing pathogens in sweet orange fruits during low temperature storage.

## MATERIALS AND METHODS

Sweet orange fruits of cultivar Blood Red were collected from an orchard located in Khal Rabat area of District Dir, Malakand Division, Khyber Pakhtunkhwa. Healthy sweet orange fruits having optimum maturity and size were graded, washed with tap water and dried. Orange were treated with water vapor at 50°C in water bath for 0, 5, 10, 15 and 20 minutes in plastic covered structure. After the completion of heat treatment, orange fruits were dried with fan air. The fruits were then packed in cardboard packages having two holes on each side for ventilation and were stored at low temperature (5°C). Data on different quality characteristics such as Total Soluble Solid (TSS), acidity, TSS/Acid ratio, reducing and non- reducing sugars and ascorbic acid content were determined according to AOAC (1990).Weight loss data was calculated by selecting ten fruits in each treatment and weighed initially. Weight loss with 15 days interval was calculated as percentage by using the following formula.

$$\text{Percent weight loss} = \frac{\text{Fresh fruit weight} - \text{weight after interval} \times 100}{\text{Fresh fruit weight}}$$

Percent disease incidence data was recorded by visually inspecting the fruits in each treatment and counted the diseased fruits after every 15 days interval during 75 days storage and percentage was find out as:

Disease incidence (%)

$$= \frac{\text{No of healthy fruit} - \text{No of diseased fruits after each interval} \times 100}{\text{Total No of Fruits}}$$

**Surface pitting:** Surface pitting was observed by scoring, based on visual observation and compared to fresh fruits. The data was converted to percentage of fruits displaying the symptoms of surface pitting.

**Statistical Analysis:** The study was conducted in two factorial Completely Randomized Design (CRD) and in order to find out the treatments differences and interactions the data pertaining to various attributes was analyzed by ANOVA technique. In case where the differences were significant among means, the least significant difference (LSD) test was used. Statistical software namely Statistix 8.1 was used for analysis of variance and least significant difference test.

## RESULTS AND DISCUSSION

**Weight loss:** Heat treatments had significant effect on percent weight loss in sweet orange fruits. Highest weight losses of 10.71% were observed in sweet orange fruits that received Vapour Heat Treatment (VHT) for 20 minutes stored for 75 days while; lowest weight losses of 8.28% were recorded in VHT 5 in 75 days storage (Table 1).

Fruit and vegetables were stored at low storage temperature so that their post -harvest life could be prolonged (Paull, 1990). The metabolic processes, that resulted ripening and senescence, were slowed down during cold storage (Tasneem, 2004). However, due to the citrus fruit chilling sensitivity (Purvis, 2004), shelf life was adversely affected during storage at temperature below 10 to 15$^{o}$C (Gross *et al*. 2002).

The increase in weight loss could be due to the chilling injury (Cohen *et al*. 1994), characterized by the development of microscopic cracks in the epicuticular waxes and, thus, triggered moisture loss and subsequent weight loss (Karuppiah, 2004).

Heat treatments have been used to induce chilling tolerance in susceptible species (Schirra *et al*. 1997). Heat treatments decreased the weight loss by changing the structure of epicuticular waxes (Schirra *et al*. 2000), filled the cuticular cracks, thereby, reducing weight loss. However, the weight loss increased with longer VHT duration could be attributed to wider and deeper cuticular cracks due to excessive heat treatments (D'hallewin and Schirra, 2000).Figure.1 (a) represents effect of vapor heat treatments on weight loss in citrus fruits during storage at chilling temperature.

**Surface pitting:** Highest surface pitting (20.00%) in sweet orange fruit was found with VHT 0 and storage for Low Temperature Storage (LTS) 75 days followed insignificantly by VHT 20 with 19.33% surface pitting. However, VHT 5 minutes resulted in lowest weight losses.

Surface pitting is a common indicator of chilling injury in orange fruit (Sala and Lafuente, 1999). Citrus fruits stored at lower storage temperature (4$^{o}$C) developed pitting symptoms and increase in storage duration further enhanced surface pitting (El-hilali *et al*. 2003). Modest heat treatments controlled the chilling injury and symptoms associated with it by improving surface of the fruit and closing the fissures (Porat *et al*. 2000). Exposure of the fruits to heat treatments for longer durations at higher temperature resulted surface pitting (Jacobi and Gowanlock, 1995).Figure1 (b)shows effect of vapor heat treatments on surface pitting in citrus fruits during storage at chilling temperature.

**Disease Incidence:** Oranges treated with VHT for 20 minutes registered highest disease incidence (18.00%) with 75 days storage at low temperature but VHT for 5-10 minutes curtailed the weight losses to lowest (6%). Disease incidence increased with increase in storage duration in fruits (D'hallewin and Schirra, 2000). Low temperature storage suppress disease incidence and delays the appearance of disease symptoms (Crisosto *et al*. 1995). However, disease symptoms on citrus fruits appeared even at temperature (5°C). The heat treatments for 5-10 minutes were effective in minimizing the disease incidence, probably by enhancing healing of injury or inducing development of lignins-like compounds that restrained pathogens entry by acting as barriers or by scoparones synthesis that might had antifungal properties (Schirra *et al.* 2000). The damage to the rind tissue by increasing cuticular cracks (Eckert and Eaks, 1988) may act as an entry route for the fungal pathogens responsible for decay. Thus, no beneficial effect of VHT durations 15 or 20 minutes at 50$^{o}$C were observed and the disease incidence was even higher than control. Figure.1(c) represents effect of vapor heat treatments on disease incidence in citrus fruits during storage at chilling temperature.

**Total soluble solids:** Total soluble solids in sweet orange fruits were significantly affected by LTS. The TSS enhanced non-significantly in fresh fruits to 10.40 ºBrix with LTS for 60 days. Thereafter registered significant increase (11.1 ºBrix) with 75 days LTS. The TSS content of the fruit is due to metabolic conversion of starch to sugar and other dissolved solid in the cell sap (Lu, 2004). Thus, the TSS content usually increases with increase in storage duration and the increase is generally higher at higher temperature (Ali *et al*. 2004). The non-significantincrease in TSS during LTS indicates that the low temperature (5$^{o}$C) decreased the metabolic activities of the tissue including the ripening and subsequent increase in total soluble solids (Serry, 2010). Beside the direct effect of low temperature, VHT may also inhibit the ripening process as well as decrease the water loss (Serrano *et al*. 2004) and both factors may collectively contribute to a slow increase in TSS during LTS. The VHT may inhibited the increase in TSS and that 60 days storage might be the critical length for the dissipation of heat treatment influence at 5°C (Sabehat *et al*. 1996).

**Acidity:** The acidity of the sweet orange fruits decreased with the advancement of low temperature storage durations. The acidity decreased significantly to the lower of 1.41% with increase in LTS duration to 75 days. Acidity decreased significantly to 1.51% in VHT for 20 minutes. Low temperature storage slowed down several metabolic activities such as respiration and ethylene production in the tissue (Wills *et al.* 1989). Thus, it was likely to observe a slow decline in acidity of sweet orange fruits. The total acidity of citrus fruits declined during storage even during the chilling exposure (Hussain *et al.* 2004). The significant reduction in acidity of the fruits during LTS may be ascribed to the dissipation of VHT influence more rapidly at room temperature than low temperature (Sabehat *et al*. 1996).

**Table-1: Effect of Vapor Heat Treatments on weight loss, surface pitting, disease incidence and TSS in citrus fruits during storage at chilling Temperature.**

| Storage Durations (Days) | Weight loss (%) | Surface Pitting (%) | Disease Incidence(%) | TSS ($^{o}$Brix) |
|---|---|---|---|---|
| **0** | 0.00 f | 0.00 e | 0.00 e | 9.94 b |
| **15** | 1.45 e | 0.00 e | 0.13 e | 9.87 b |
| **30** | 2.14 d | 1.73 d | 1.33 d | 9.91 b |
| **45** | 3.71 c | 3.60 c | 2.93 c | 10.25 b |
| **60** | 7.24 b | 9.20 b | 6.27 d | 10.40 ab |
| **75** | 9.50 a | 16.40 a | 10.53 a | 11.10 a |
| **LSD at α 0.05** | **0.286** | **1.279** | **0.857** | **0.832** |
| **Heat Treatments (VHT)** | | | | |
| **VHT 0** | 4.53 a | 6.67a | 2.78 b | 10.22 |
| **VHT 5** | 3.53 c | 2.78 b | 1.44 c | 9.96 |
| **VHT 10** | 3.60 c | 3.00 b | 1.44 c | 10.11 |
| **VHT 15** | 3.95 b | 6.78 a | 5.67 a | 10.37 |
| **VHT 20** | 4.44 a | 6.56 a | 6.33 a | 10.57 |
| **LSD at α 0.05** | **0.261** | **1.168** | **0.783** | **NS** |
| **Interaction (VHT X Storage durations)** | | | | |
| **Significance** | * | * | * | NS |
| **LSD at α 0.05** | 0.640 | 2.862 | 1.918 | --- |
| **Fig** | 1. (a) | 1. (b) | 1. ( c ) | --- |

Means in column do not differ significantly that are followed by similar letter(s)
NS= non-significant.
*= Significant at 5 percent probability.
VHT= Vapor Heat Treatment

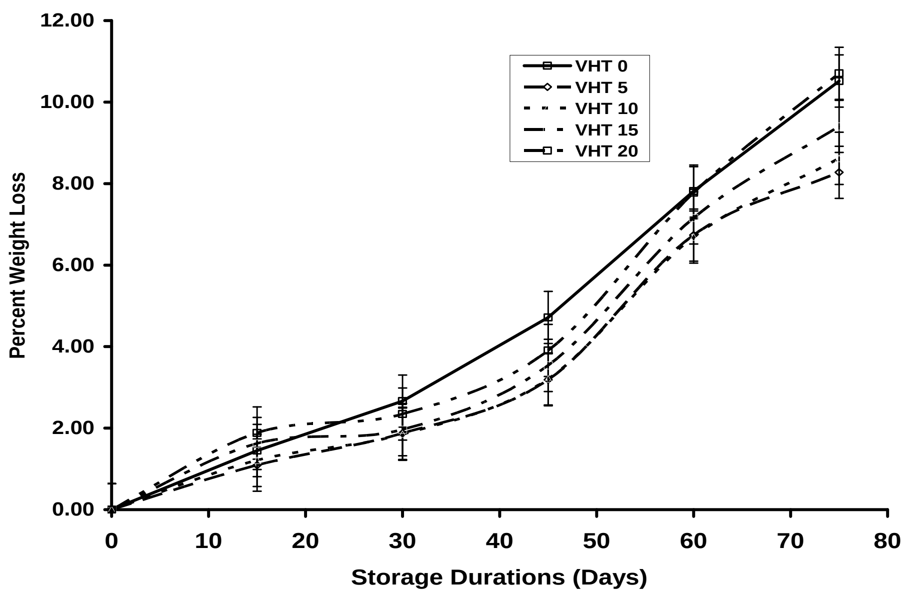


**Fig. 1 (a): Effect of vapor heat treatments on weight loss in citrus fruits during storage at chilling temperature. The error bars represent LSD at p≤ 0.05.**

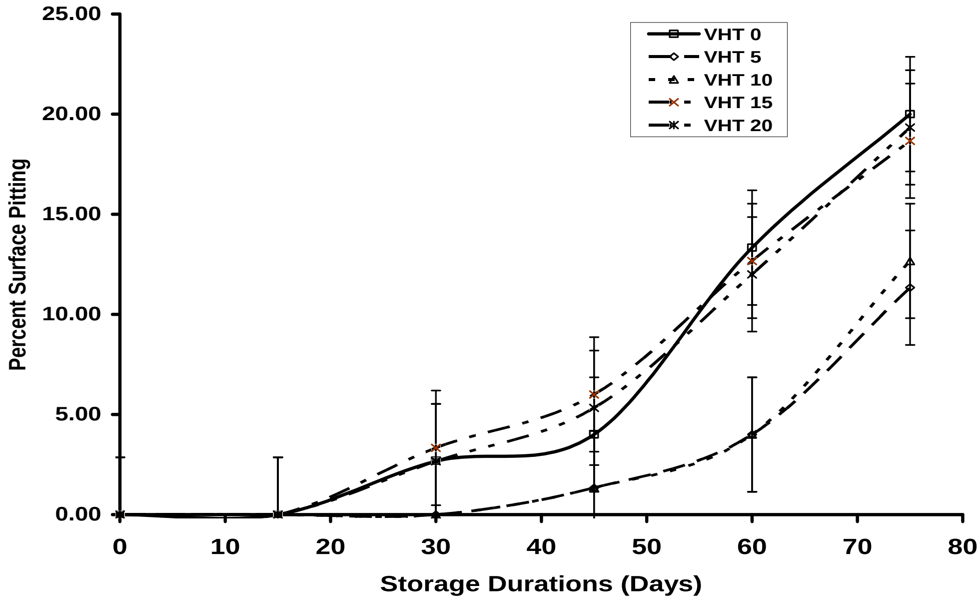


**Fig.1 (b): Effect of vapor heat treatments on surface pitting in citrus fruits during storage at chilling temperature. The error bars represent LSD at p≤ 0.05.**

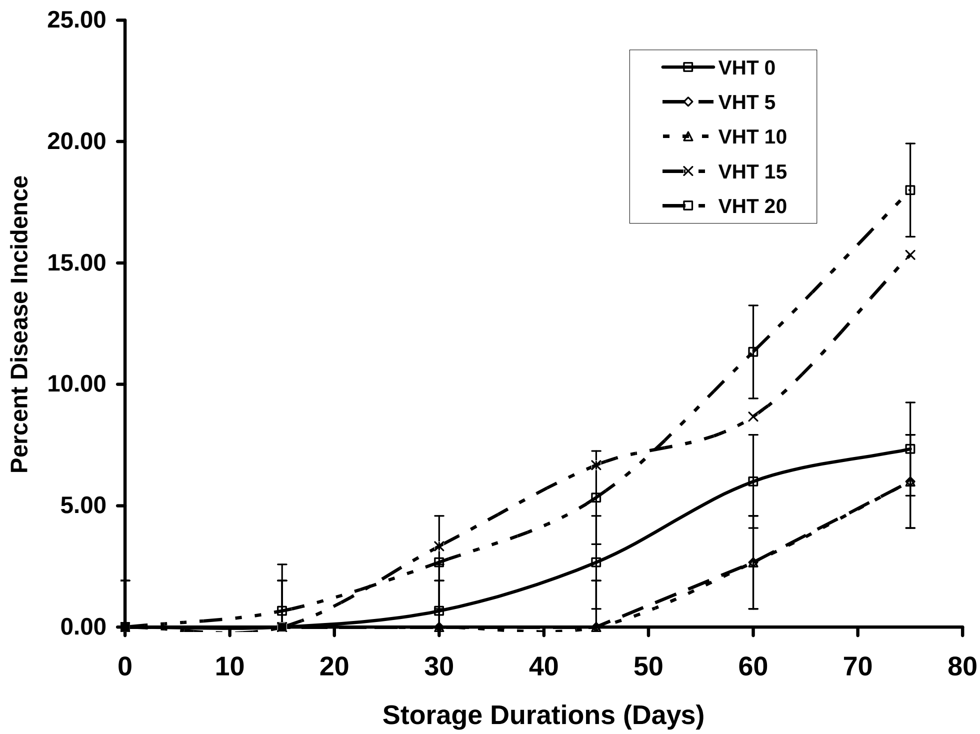


**Fig.1(c): Effect of vapor heat treatments on disease incidence in citrus fruits during storage at chilling temperature. The error bars represent LSD at p≤ 0.05.**

**TSS/ Acid Ratio:** The TSS/ Acid ratio increased and reached to the highest of 7.63 after 75 days of LTS (5° C). The VHT effect was also significantbut was duration dependent. Whereas VHT for 0-15 minutes at 50°C had no significant effect, longer VHT (20 minutes) resulted in higher TSS/Acid ratio to 7.00 (Table 2). During prolong fruit storage the starches are converted into sugars that increases the TSS (Lum and Norazira, 2011) whereas high storage temperature increases the respiration rate resulting in use of organic acid as substrate for respiration (Vicente *et al*. 2002). Sugar acid ratio relates to TSS and acidity and the soluble solids percentage increased whereas acidity reduced in storage of sweet orange fruit even at low temperature, it is likely to observe the increase in TSS Acid ratio (Marcilla *et al*. 2006).

**Reducing sugar:** Reducing sugars continued to reduce gradually as the LTS duration progressed. The reducing sugars declined to the lowest of (4.67%) with 75 days LTS (5°C). The VHT also had non-significant effect on reducing sugars during LTS. Among heat treatments, VHT 0 had highest reducing sugars of 5.08% followed by VHT 5 5.03% and subsequent increase in VHT durations resulted in decrease in reducing sugars with lowest reducing sugars of 4.79 in sweet orange fruits receiving VHT 20. Increasing VHT duration decreased the chilling induced inhibition of respiration and subsequently resulted in greater normal loss of reducing sugars. As the reducing sugars are consumed in respiration, their decline is obvious with increasing storage duration (Bajwa *et al.* 2003). The gradual decline in reducing sugars at LTS confirm that the chilling hinder respiration during chilling exposure (Kurets *et al*. 2003).

**Ascorbic acid:** Ascorbic acid continued to decline with incremental increase in LTS duration and finally reached the lowest value of 29.21 mg/100g with 75 days LTS. The highest ascorbic acid (40.22mg/100g) was recorded in control treatment followed by VHT 5 minutes (39.26mg/100g). Escalating VHT durations to 15-20 minutes enhanced the degradation of ascorbic acid content in sweet orange fruit and reached the lowest ascorbic acid of 35.76 mg/100g with VHT for 20 minutes.

Prolonged storage at high storage temperatures or at chilling temperatures adversely affected ascorbic acid in citrus (Parviainen and Nyyssonen, 1992). The incremental reduction in ascorbic acid with increase in LTS indicates that despite ascorbic acid may be particularly sensitive to chilling conditions in sweet orange fruits (Kaul and Siani, 2000). Citrus fruits are vulnerable to chilling injury during cold storage that hasten losses in ascorbic acid content even before any visible symptoms of chilling injury appear in chilling sensitive crops (Lee and Kader, 2000).

**Table-2: Effect of Vapor Heat Treatments on Acidity, TSS/ Acid Ratio, Reducing-Sugars and Ascorbic-acid in citrus fruits during storage at 5 °C**

| Storage Durations (Days) | Acidity (%) | TSS/ Acid Ratio | Reducing Sugars (%) | Ascorbic Acid (mg/100g) |
|---|---|---|---|---|
| **0** | 1.64 a | 6.06 c | 5.09 | 46.12 a |
| **15** | 1.64 a | 6.03 c | 5.05 | 44.12 a |
| **30** | 1.61 ab | 6.15 c | 4.99 | 39.19 b |
| **45** | 1.57 bc | 6.56 bc | 4.93 | 36.85 b |
| **60** | 1.52 c | 6.88 b | 4.79 | 32.74 c |
| **75** | 1.41 d | 7.63 a | 4.67 | 29.21 d |
| **LSD at α 0.05** | **0.060** | **0.560** | **NS** | **2.555** |
| **Heat Treatments (VHT)** | | | | |
| **VHT 0** | 1.61 a | 6.40 bc | 5.08 | 40.22 a |
| **VHT 5** | 1.59 a | 6.16 c | 5.03 | 39.26 ab |
| **VHT 10** | 1.58 ab | 6.42 bc | 4.85 | 37.92 a/c |
| **VHT 15** | 1.53 bc | 6.78 ab | 4.86 | 37.04 bc |
| **VHT 20** | 1.51 c | 7.00 a | 4.79 | 35.76 c |
| **LSD at α 0.05** | **0.055** | **0.511** | **NS** | **2.332** |
| **Interaction (VHT X Storage durations)** | | | | |
| **Significance** | NS | NS | NS | NS |
| **LSD at α 0.05** | --- | --- | --- | --- |
| **Fig** | --- | --- | --- | --- |

Means in column do not differ significantly that are followed by similar letter(s)
NS= non-significant *= Significant at 5 percent probability. VHT= Vapor Heat Treatment

## REFERENCES


Ali, M. A., H. Raza., M. A. Khan and M. Hussain (2004). Effect of Different Periods of Ambient Storage on Chemical Composition of Apple Fruit. Int. J. Agri. Biol.6(2): 568–571.

AOAC. (1990). Official methods of analysis. Analytical Chemist. 15th Ed. Washington DC, USA.

Arif, A., Y. Zafar, M. Arif and E. Blumwald(2013). Improved growth, drought tolerance and ultrastructural evidence of increased turgidity in tobacco plants overexpressing arabidopsis vacuolar pyrophosphotase AVP1. Mol. Biotechnol. 54(2): 379-392.

Bajwa, E. E., Z. Naeem, J. Anjum and Nazir (2003). Development, standardization and storage studies on watermelon-lemon. Pakistan J. Food Sci. 12: 21-24.

Cohen, E., B. Shapiro, Y. Shalom and J.D. Klein(1994). Water loss: a nondestructive indicator of enhanced cell membrane permeability of chilling injured citrus fruit. J. Amer. Soc. Hort. Sci. 119:983-986.

Crisosto, C. H., F. G. Mitchell and R. S. Johnson(1995). Factors in fresh market stone fruit quality. Postharvest News Inform. 5: 17–21.

Eckert, J. W and I. L. Eaks(1988). Postharvest disorders and diseases of citrus fruit. The Citrus Industry, University of California Press, Berkeley. 179-260.

D’hallewin, G. and M. Schirra(2000). Structural changes of epicuticular wax and storage response of ‘Marsh’ grapefruits after ethanol dips at 21 and 50°C. Proc. 4th Intl. Conf. on Postharvest:441-442.

El-hilali, F., A. Ait-Oubahou, A. Remah and O. Akhayat(2003). Chilling injury and peroxidase activity changes in “fortune” mandarin fruit during low temperature storage. Bulg. J. Plant Physiol. 29(1-2): 44–54.

Gross, K.C., C. Y. Wang and M. Saltveit (2002). The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Crops. Available at:http://www.ba.ars.usda.gov/hb66/index.html.

Hussain. I., M. Asif, M. Ahmed, M. Khan and I. Shakir (2004). Effect of Uni-Packaging on the Post-Harvest Behavior of Citrus Fruits in Khyber Pakhtunkhwa.PakistanJ.Nutr.3 (6): 336-339.

Jacobi, K.K. andD. Gowanlock(1995). Ultrastructural studies of ‘Kensington’ mango heat injuries. Hort Science. 30: 102–103.

Khan, G.A., A. Rab, M. Sajid, and Salimullah (2007). Effect of heat and cold treatments on post-harvest quality of sweet orange cv. Blood Red. Sarhad. J. Agric. 1(23): 39-46.

Karuppiah, K.J. J. (2004). Heat treatments for controlling postharvest diseases and chilling injury in Florida citrus. The graduate school of the University of Florida.

Kaul, R. K. and S. P. S. Saini(2000). Compositional changes during storage and concentration of kagzi lime juice. J. Sci. Indust. Res. 59: 395-399.

Kurets,V. K., S. N. Drozdov, E. G. Dembo, N. I. Khilkov and S. A. Trofimova (2003). Effect and after effects in respiration of intact plants. Russ. J. Plant. Physiol. 50: 308-312.

Lafuente, M. T., L. Zacarias, J. M. Sala, M. T. Sánchez-ballesta, M. T. Gosalbes, J. F. Marcos, L. and G.Candelas(2005). Understanding the basis of chilling injury in citrus fruit. Acta Hort. 682: 831–842.

Lafuente, M.T., L. Zacarías (2006). Postharvest physiological disorders in citrus fruit. Stewart Postharvest Rev. 1, 2.

Lee, S. K., and A. A. Kader (2000). Preharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharvest Biol Tec. 20(3): 207–220.

Lu, R (2004). Multispectral imaging for predicting firmness and soluble solids content of apple fruit. Postharvest Biol Tec. 31:147-157.

Lum, M. S. and M. A. Norazira. (2011). Effects of hot water, submergence time, and storage duration on quality of dragon fruit (*Hylocereus polirhizuz*). J. Agri. Sci. 3(1): 146-152.

Lurie S., T. Jemric., A. Weksler., R. Akiva and Y. Gazit (2004). Heat treatment of Oroblanco citrus fruit to control insect infestation.Postharvest Biol Tec.34(3): 321-329.

Marcilla, A., M. Zarzo and M. A. Del Río (2006). Effect of storage temperature on the flavor of citrus fruit. Span J Agric Res.4(4): 336-344.

Parviainen, M. T. and K. Nyyssonen (1992). Ascorbic acid. In: A. P. D. Leenheer, W. E. Lambert and H. Nelis (Eds.), Modern Chromatographic Analysis of Vitamins. New York: Marcel Dekker Inc.

Paull, R. E.(1990). Chilling injury of crops of tropical and subtropical origin. In Ed. C. Y.

Piccinelli, A. L., M. G. Mesa., D. M. Armenteros., M. A. Alfonso. A. C. Arevalo. L. Campone and L. Rastrelli. (2008). HPLC-PDA-MS and NMR Characterization of C-Glycosyl Flavones in a Hydroalcoholic Extract of Citrus aurantifolia Leaves with Antiplatelet Activity. J. Agric. Food Chem. 56: 1574–1581.

Porat, R., A. Daus, B. Weiss, L. Cohen, E. Fallik and S. Droby (2000). Reduction of postharvest decay in organic citrus fruit by a short hot water brushing treatment. Postharvest Biol. Technol. 18:151-157.

Purvis, A. C. (2004). Regulation of oxidative stress in horticultural crops. Hort Science. 39: 930-932.

Sabehat, A., D. Weiss and S. Lurie(1996). The correlation between heat shock protein accumulation and persistence and chilling tolerance in tomato fruit.Plant Physiol. 110: 531–541.

Sala, J. M. and M. T. Lafuente (1999). Catalase in the heat-induced chilling tolerance of cold-stored hybrid “Fortune” mandarin fruits. J. Agric. Food Chem. 47: 2410-2414.

Schirra, M. and G. D Hallewin (1997). Storage performance of Fortune mandarins following hot water dips. Postharvest Biol. Technol. 10:229-238.

Schirra, M., G. D. Hallewin, S. Ben-Yehoshua, and E. Fallik (2000). Host-pathogen interactions modulated by heat treatment. Postharvest Biol. Technol. 21:71-85.

Serrano, M., D.M.Romero, S. Castillo, F. Guillen and D. Valero (2004). Role of calcium and heat treatments in alleviating physiological changes induced by mechanical damage in plum. Postharvest Biol. Technol.34: 155- 167.

Serry, N. K. H. (2010). Some modified atmosphere packaging treatments reduce chilling injury and maintain postharvest quality of Washington navel orange. JHSOP. 2(3):108-113.

Tasneem, A. (2004). Postharvest treatments to reduce chilling injury symptoms in stored mangoes. Masters, McGill University.

Vicente, A. R., G. A. Martinez, R. M. Civello and A. R. Chaves(2002). Quality of heat-treated strawberry fruit during refrigerated storage. Postharvest Biol. Technol. 25: 59-71.

Wills, R. B. H., W. B. McGlasson, D. Graham, T. Lee, and E. G. Hall (1989). Postharvest: An Introduction to the Physiology and Handling of Fruit and Vegetables. Van Nostrands Reinhold,New York,pp. 17-52.