Indian Journal of Agricultural Sciences **88** (11): 1760–4, November 2018/Article

Wet heat treatment of Nagpur mandarin (*Citrus reticulata*) fruits to reduce decay loss

DINESH KUMAR[1], LALLAN RAM[2], SUNIL KUMAR[3] and ARCHANA KHADSE[4]

ICAR-Central Citrus Research Institute, Amravati Road, Nagpur, Maharashtra 440 010

Received: 04 June 2018; Accepted: 27 June 2018

ABSTRACT

The study was conducted to determine the effects of hot water, temperature, duration of submergence under different storage conditions. Nagpur mandarin (*Citrus reticulata* Blanco) fruits subjected to wet heat treatments, viz. 60^0C for 30 and 60 seconds, 55^0C for 60 and 90 seconds, 50^0C for 90 and 120 seconds, 45^0C for 120 and 150 seconds and control. The observations were recorded for 21 days under ambient condition and 60 days under refrigerated condition. Physico-chemical and sensory attributes revealed that with low physiological loss in weight (10.41%) with high TSS (11.30%), juice recovery (47.51%) with lower deformation (10.2 mm) and Vitamin 'C' content (36.33 mg/100 ml) with fruits treated at 50^0C ±1.5 min. The microbial load of bacteria (1.07 log CFU/ml) as well as yeast and mold count (0.69 log CFU/ml) was found lower with high temperature (50˚C) and short duration (90 sec). Scanning Electron Microscope (SEM) image revealed the occurrence of melting and redistribution of natural epicuticular wax on the fruit surface, plugging with cracks and stomata which could have served as potential pathogen invasion sites.

Key words: Duration, Physico-chemical parameters, SEM, Storage condition, Temperature

Citrus is one of the very important fruit crop and has occupied 3rd place after mango and banana in India both in terms of area and production. Our country is the leading producer of loose jacketed Nagpur mandarin (*Citrus reticulata* Blanco) which is well known for its aroma and flavour. The post-harvest losses have been recorded substantially in citrus due to several factors involved from fruit harvesting to consumption chain. The post-harvest losses can be minimized with the adoption of advance technologies to extend the marketing distance and holding periods of commodities after harvest.

There has been increasing interest in recent years about the use of heat treatments as a post harvest management strategy mainly to control insect pest and diseases. Chemical prevention can be substituted by heat treatment. This treatment may eliminate infections by removing spores and thus directly acting on viability and enhancing defense mechanisms of fruits and ultimately inhibiting the growth of pathogens (Schirra *et al.* 2000). Postharvest dips are applied for a few minutes at high temperatures because fungal spores and latent infections are either on the surface or in the first few cell layers under the peel of the fruit (Lurie 1998). The storage life of fruits and vegetables are prolonged by Heat treatment technology. This is an alternative, safe as well as an eco-friendly procedure with increasing acceptability. This is highly effective to reduce the chemical use for post harvest management of pathogens and provide the safer fruits to consumers. It is used to effectively control the occurrence of postharvest disease in various different commodities (Fallik 2004). The treatment of fruits with hot-water-dip before storage at temperatures above 40°C are successful in controlling the spoilage percentage by lowering the microbial load, enhancing the resistance of fruit tissues and thus influencing host metabolism (Barkai-Golan and Philips 1991). Many researchers have also reported the benefits of hot water treatment for controlling citrus decay (Schirra and D'hallewin 1997, Porat *et al.* 2000, Palou *et al*. 2001, Ben-Yehoshua 2003). In citrus fruits, hot water dips of temperature 50-53°C for 120-180 seconds have proven to be helpful as curing (35°C for 3 days) in controlling different postharvest diseases and is cheap because of its shorter treatment duration. Heat is usually applied to a fruit commodity via air or water (Barkai-Golan and Phillips 1991). However, water is more efficient than air by virtue of its higher heat transfer co-efficient (Jacobi *et al.* 1993, Shellie and Mangan 1993). It has been reported that hot water treatments have been successful in controlling postharvest diseases in countries like USA (Brown and Baraka 1997), Israel (Rodov *et al.* 1997) and Italy (Dettori *et al*. 1996). In the present study we examined the optimum temperature

[1]Principal Scientist (e mail: dineshscn@gmail.com), [3]Assistant Chief Technical Officer (e mail: sunil _ut2004@yahoo.co.in), [4]Research Associate (e mail: archanakhadse05@gmail.com) ICAR- Central Citrus Research Institute. [2]Director (e mail: lallanram09@gmail.com), ICAR-Central Institute of Horticulture, Medziphema, Nagaland.

and exposure duration required to reduce the development of pathogens and minimize the decay and subsequently post-harvest losses.

MATERIALS AND METHODS

The present investigation was carried out at ICAR-Central Citrus Research Institute, Nagpur in Post Harvest Technology Laboratory during the year 2012-2013. Nagpur mandarin fruits were collected from the farmer orchard and sorted; damaged and irregular fruits were discarded following the washing of mature fruits in running water and thereafter in distilled water and dried for removal of surface moisture. Thereafter, the fruits were dipped in hot water at different temperature and durations, viz. 60°C + 30 sec, 60°C + 60 sec, 55°C + 60 sec, 55°C + 90 sec, 50°C + 90 sec, 50°C +120 sec, 45°C + 120 sec, 45°C + 150 sec and control. Twenty five fruits were used in each treatment and replicated four times in CRD design. Fruits immersed in cold tap water for 120 sec acted as controls. Following the treatments fruits were dried at room temperature and packed in CFB boxes and stored at ambient temperature (25±30°C and 40-45% RH) and refrigerated condition (6±1°C and 90-95% RH). The observation was recorded initially and periodically at an interval of 7 days in *ambia* bahar. The observations on fruit firmness, colour, TSS, PLW, acidity, vitamin C, flavor, microbial evaluation and organoleptic profile were taken at 7 days interval in ambient condition and 14 days interval under refrigerated condition which was continued till 60 days. Finally for 21 days under ambient condition and 60 days under refrigerated condition. However, after assessment the samples were analyzed for sensory attributes; panel list recorded their score about color, flavor, texture, shriveling on a 9 point Hedonic Scale.

Nagpur mandarin peel disks extruded from the HWT treated fruits, which was dissected in 3 thin sections. The section was dipped in 2.5% glutaraldehyde solution over night followed by washing with ethanol in successive manner for dehydration, 50% to 100% ethanol at 600 sec of successive intervals according to JEOL manual (Anon 2013). The samples were mounted on thin section holder, directly on an appropriate size aluminum sample stub with carbon tape, and then it was loaded for SEM image. The sample was analyzed by FEI model inspect S (D8858) automated SEM.

The microbiological evaluation of hot water treated Nagpur mandarin fruits stored at ambient temperature (25±30°C and 40-45% RH) and refrigerated condition (6±1°C and 90-95% RH) was done by recording the total yeast and mold counts along with total aerobic count by washing the fruits with sterile distilled water. The fruit washings were serially diluted, and 0.1 ml of each dilution was plated on sterile potato dextrose agar and nutrient agar. The potato dextrose agar and nutrient agar was autoclaved at 120°C and 15 1bs pressure for 20 min and was poured in separate sterile Petri dishes. The number of colony forming units (CFU) on Potato Dextrose agar was determined after 3 days and that on Nutrient agar was determined after 1 day and of incubation at 37^0C. Total aerobic plate count was enumerated using 'spread plate technique' on Nutrient agar and Potato Dextrose agar. Total aerobic count was taken and expressed in log CFU/ml.

Color was measured using a digital colorimeter which display L*- lightness/darkness, a*- redness, b*- yellowness and a/b ratio – orange colour. A Petri dish containing 25 ml of Nagpur mandarin segments juice was placed into the lighting system of colorimeter. The TSS of the representative Nagpur mandarin segment juice was determined by using digital refractometer at temperature 25°C. The titrable acidity and ascorbic acid were determined by the method given by AOAC (1990). Segment juice was titrated against 0.1 N NaOH using Phenolphthalein (1%) as an indicator. The appearance of the light pink colour was taken as end point. The acidity of the fruit was expressed in g of citric acid per 100 ml of juice. For ascorbic acid estimation, five ml of segment juice was mixed with 20 ml of 3% metaphosphoric acid as buffer which was titrated with 2, 6 dichlorophenol indophenols dye till the light pink colour appeared as an end point. The result was expressed in mg of ascorbic acid per 100 ml of juice. The experimental data was statistically analyzed by using the method of Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

Physico-chemical parameters

Hot water treatment notably influenced the physico-chemical parameters of Nagpur mandarin fruits. Study revealed that treatment 50°C for 90 sec at 60 days storage period in refrigerated condition had recorded the least (10.41%) physiological loss in weight (PLW) as compared to other treatments. This might be due to the moisture loss from fresh fruit by vapor- phase diffusion and respiration leads to weight reduction. The treatment 50°C for 90 sec showed lower deformation of fruits (11.30 mm) with maximum total soluble solids (11.30%) and Vitamin C content (36.33 mg/100ml) which reflects the retention of fruit quality, similar results were obtained by Hong *et al.* (2007). However, maximum (47.51%) juice recovery with lower deformation (10.20 mm) was recorded in fruits treated at 50°C for 120 sec as shown in (Table 1). The

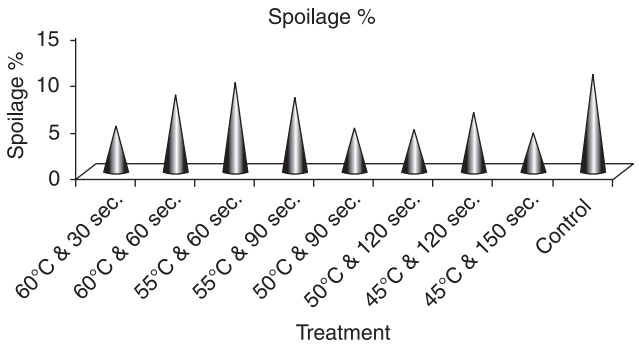

Fig 1 Spoilage % of hot water treatment after 60 days of refrigerated condition.

Table 1 Effect of heat treatment on storage ability of Nagpur mandarin in refrigerated condition after 60 days

Treatment	PLW (%)	Deformation at hardness (mm)	Juice (%)	TSS (°B)	Acidity (%)	Vit.C (mg/100 ml)
600C +30 sec.	13.84	13.30	41.00	10.07	0.72	29.83
600C +60 sec.	14.91	12.07	42.67	10.30	0.64	33.33
550C +60 sec.	12.26	13.73	39.17	9.70	0.76	29.17
550C +90 sec.	13.73	12.83	43.80	10.13	0.82	33.83
500C +90 sec.	10.41	11.30	45.97	11.30	0.76	36.33
500C +120 sec.	12.15	10.20	47.51	10.77	0.69	34.50
450C +120 sec.	12.60	13.23	44.90	9.67	0.83	32.50
450C +150 sec.	14.46	12.77	41.36	9.90	0.71	30.33
Control	16.02	15.80	37.70	10.00	0.86	30.17
CD(P=0.05)	2.57	2.47	5.57	0.96	NS	3.11

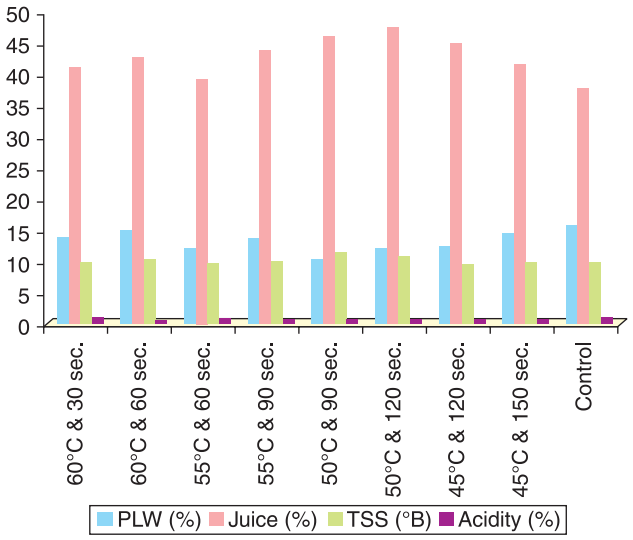

Fig 2 Effect of heat treatment on storage life of Nagpur mandarin in ambient condition after 21 days.

similar pattern in changes of physico-chemical parameters were also observed for the fruits stored in ambient condition (Fig 2).

Microbiological study

In treatment 50°C for 90 sec the microbial load recorded after 21 days of storage on Nutrient agar (1.07 log CFU/ml) and Potato dextrose agar (0.69 log CFU/ml) under ambient condition which revelead that, bacterial as well as yeast and mold count was found lower with high temperature and short duration but it increased in fruits not dipped in hot water similar trend was observed in 60 days refrigerated condition (Fig 4 and 5). The data revealed that the spoilage percent with treatment of 50°C for 90 sec was found to be minimum as compared with control (Fig 1). Citrus fruits with hot water treatment can result in uniform distribution of natural epicuticular wax on fruit surface thereby plugging cracks and stomata and inhibiting pathogen invasion (e.g. *Botrytis cinerea* whose spores can germinate and penetrate the surface of fruit) and transpiration (Porat *et al.* 2000, Lydakis and Aked 2003). In this way, sites of fungal penetration are minimized by sealing natural openings and visible cracks in the epidermis of treated fruit with natural wax components present on the cuticle (Rodov *et al.* 1995, Schirra and D'hallewin 1997, Porat *et al.* 2000, Fallik 2004). This mechanism can prevent weight loss from transpiration and the development of decay and can potentially assist in maintaining the good appearance and taste in fruit. Similarly, hot water treatment exerted no adverse effects on the sensory attributes of Nagpur mandarin.

Evaluation in scanning electron microscope (SEM)

Scanning electron microscope (SEM) examination of Nagpur mandarin after wet heat treatment (WHT) at 50°C for 90 sec further indicated that the treatment cleaned the fruits and smoothed the fruit epicuticular waxes (Fig 3 A

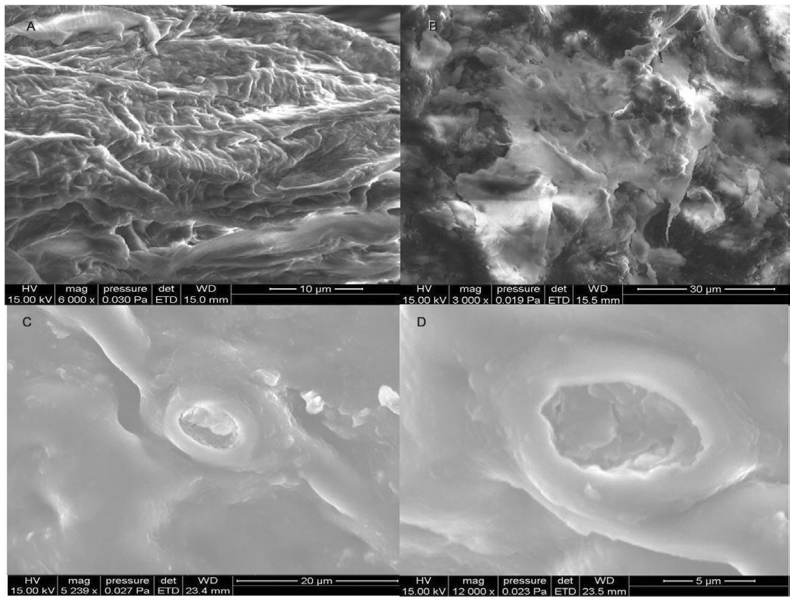

Fig 3 SEM image of Nagpur mandarin fruit surface after hot water treatment. A-surface of control fruit, B-surface of hot water treated fruit, C and D-stomata of hot water treated fruit.

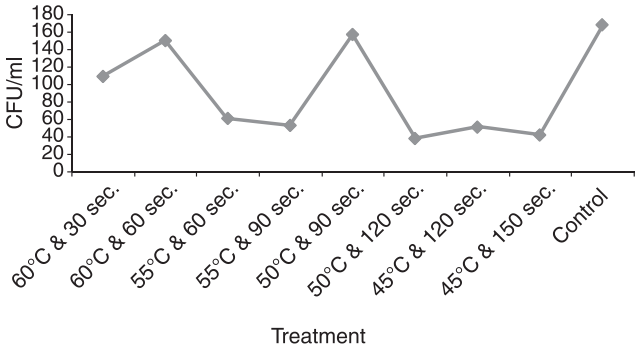

Fig 4 Effect of hot water treatment on total bacterial count (CFU/ml) on Nagpur mandarin fruits in 60 days refrigerated condition.

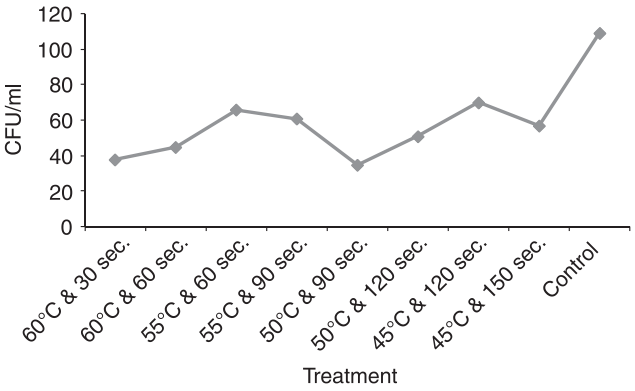

Fig 5 Effect of hot water treatment on total yeast and molds count (CFU/ml) on Nagpur mandarin fruits in 60 days refrigerated condition.

and C). So that, it covered and sealed the stomata (Fig. 3 A and D) and microscopic cracks on the fruit surface. Several recent studies have confirmed that hot water dips usually for 120-180 seconds at 53°C with or without the addition of fungicides were capable of reducing decay in wide variety of citrus cultivars (Rodov *et al*. 1995, Schirra and D'hallewin 1997).

Cleaning and disinfection of the fruits surface by hot water treatment was confirmed by SEM analysis (Fig 3 A, B, C and D). Another effect of the hot water treatment was that it melted the fruit epicuticular waxes and thus covered and sealed the stomata and cracks on the fruit surface, these could have served as potential pathogen invasion sites. Similar findings were reported by Schirra and D'hallewin (1997) with hot water treatment while carrying out study with Fortune mandarins.

Sensory evaluation

Hot water treatment cleaned the fruit and improved their general appearance without affecting other quality parameters. During the entire storage period, the fruit, particularly that treated at 50°C hot water for 90 sec gained higher scores in color, flavor, texture and lower score in fruit shriveling on a 9 point Hedonic Scale and overall visual quality than untreated controls. Treatment with 50^0C hot water for 90 sec markedly improved fruit appearance, making them cleaner and glossier. Similar results of improved general appearance of the fruit without alteration of their quality parameters were reported previously (Schirra and D'hallewin 1997, Porat *et al.* 2000, Smilanick *et al.* 2003, Schirra *et al*. 2004). It can be inferred that hot water treatment with 50°C for 90 sec can significantly minimize the postharvest loss of Nagpur mandarin fruits without any external application of the fungicidal treatment under the refrigerated storage condition, with non pesticidal residual effects promoting the eco-friendly concept for higher marketability.

ACKNOWLEDGEMENT

We gratefully acknowledge the guidance and necessary facilities provided by Dr V J Shivankar, Director, ICAR-Central Citrus Research Institute, Nagpur for constant encouragement and providing the necessary facilities and supporting staff members of processing laboratory in carrying out the experiments successfully. Authors also thankful to Dr K. Karthikeyan, ICAR-NBSS and LUP Nagpur for providing and imaging of samples in scanning electron microscope.

REFERENCES

AOAC. 1990. *Official Methods of Analysis*. Association of Analytical Chemists, 15th Edn. Washington DC.

Anonymous. 2013. *Preparation of biological specimens for electron microscopy*. JEOL manual, Tokyo, Japan.

Barkai Galon R and Phillips D J. 1991. Postharvest heat treatment of fresh fruits and vegetables for decay control**.** *Plant diseases* **75**: 1085–9.

Ben-Yehoshua S. 2003. Effect of postharvest heat and UV applications on decay, chilling injury and resistance against pathogens of citrus and other fruits and vegetable. *Acta Horticulturae* **599**: 159–73.

Brown G E and Baraka M A. 1997. Effect of washing sequence and heated solutions to degreened Hamlin oranges on Diplodia stem-end rot, fruits colour and phytotoxicity. (In) *Proceedings of the 8th Congress of the International Society of Citriculture* **2**: 1164–70.

Dettori A, D'Hallewin G, Agabbio M, Marceddu S and Schirra M. 1996. SEM studies on *Penicillium italicum*-"stay ruby" grapefruit interactions as affected by hot water dipping. (*In*) *Proceedings of the 8th Congress of the International Society of Citriculture* **2**: 1158–63.

Fallik E. 2004. Pre-storage hot water treatments (immersion, rinsing and brushing). *Postharvest Biology Technology* **32**: 125–34.

Hong S, Lee H and Kim D. 2007. Effect of Hot water treatment on the storage stability of Satsuma mandarin as a post harvest decay control. *Postharvest Biology Technology* **43**: 271–9.

Jacobi K, Coates L and Wong L. 1993. Heat disinfestations of mangoes: effect on fruit quality and disease control. in: *postharvest handling of tropical Fruits,* pp 280–7. Champ B R, Highly E , Johnson G I (Eds). The Australian Centre for International Agriculture Research, Brisbane, Australia.

Lurie S. 1998. Postharvest heat treatments. *Postharvest Biology Technology* **14**: 257–69.

Lydakis D and Aked J. 2003. Vapor heat treatment of Sultanina table grapes. II: Effect on postharvest quality. *Postharvest Biology Technology* **27**: 117–26.

Palou L, Smilanick J L, Usall J and Vihas I. 2001. Control of postharvest blue and green molds of oranges by hot water, sodium carbonate, and sodium bicarbonate. *Plant Diseases* **85** (4): 371–6.

Panse V G and Sukhatme P V. 1967. *Statistical Methods for Agricultural Workers*, 2nd edn. ICAR, New Delhi.

Porat R, Daus A, Weiss B, Cohen L, Fallik E and Droby S. 2000. Reduction of postharvest decay in organic citrus fruit by a short hot water brushing treatment. *Postharvest Biology Technology* **18**: 151–7.

Rodov V, Ben-Yehoshua S, Albagli R and Fang D Q. 1995. Reducing chilling injury and decay of stored citrus fruit by hot water dips. *Postharvest Biology Technology* **5**: 119–27.

Rodov V, Peretz J, Ben-Yehoshua S, Agar T and Hallewin G. 1997. Heat application as complete or partial substitutes for post harvest fungicide treatments of grapefruit and oroblanco fruits. (*In)Proceedings of the 8th Congress of the International Society of Citriculture* **2**: 1153–7.

Schirra M and D'hallewin G. 1997. Storage performance of fortune mandarins following hot water dips. *Postharvest Biology Technology* **10**: 229–38.

Schirra M, D'hallewin G, Ben-Yeboshua S and Fallik E. 2000. Host-pathogen interactions modulated by heat treatment. *Postharvest Biology Technology* **21**: 71–85.

Schirra M, Mulas M, Fadda A and Cauli E. 2004. Cold quarantine responses of blood oranges to postharvest hot water and hot air treatments. *Postharvest Biology Technology* **32**: 191–200.

Shellie K C and Mangan R L. 1993. *Disinfestation: effect on nonchemical treatment on market quality of fruits*, pp. 304–10. (*In*) Postharvest Handling of Tropical Fruits. Champ B R Champ, Highly E and Johnson G I (Eds). The Australian Centre for International Agriculture Research, Brisbane, Australia.

Smilanick J L, Sorenson D, Mansour M, Aieyabei J and Plaza P. 2003. Impact of a brief postharvest hot water drench treatment on decay, fruit appearance, and microbe populations of California lemons and oranges. *Horticultural Technology* **13**: 333–8.