J. Hortic. Sci.
Vol. 18(1) : 189-194, 2023

https://doi.org/10.24154/jhs.v18i1.2162

Original Research Paper

Effect of hot water treatments on physiological and biochemical changes in mango cv. Banganapalli during storage at ambient temperature

Anand A.[1]*, Rao D.V.S.[2], Narayana C.K.[2], Kurian R.M.[3], Ranjitha K.[2] and Shivashankara K.S.[4]

[1&2]Division of Postharvest Technology & Agricultural Engineering,
ICAR-IARI Outreach Programme Centre, Bengaluru, Karnataka, India
[3]Division of Fruit Crops, [4]Division of Basic Sciences,
ICAR-Indian Institute of Horticultural Research, Bengaluru - 560089, Karnataka, India
*Corresponding author Email : anusreehorti@gmail.com

ABSTRACT

Mango fruits majorly suffers from anthracnose and fruit fly infestations during storage, transportation and marketing. Hot water treatments (HWTs) at specific levels have shown to control the incidence of these important threats. Application of HWT not only act as a quarantine measure, but also maintains the quality and enhance the marketability of fruits, even at room temperature (RT), leading to its vast applicability in local / international markets. In this study, post harvest application of HWTs (48°C for 60 min and 55°C for 10 min) in mango cv. Banganapalli recorded reduced ethylene production rate, physiological loss in weight, improved sugar content, ascorbic acid, total carotenoids, phenolics and antioxidants compared to control. Combination of HWTs (48°C for 60 min followed by 55°C for 10 min) resulted in degradation of some quality parameters compared to individual HWT and control.

Keywords : Antioxidants, hot water treatments, mango cv. Banganapalli, phenols, quality

INTRODUCTION

Mango (*Mangifera indica*) is climacteric fruit with high respiration rate and have limited shelf life under ambient conditions. Sensitivity of fruits to decay, low temperature injury, perishability of fruits due to ripening and softening affects the handling, transport and storage potential of mangoes (Hoa *et al*., 2002). Mango cv. Banganapalli is one of the major export cultivars in India (Rao and Rao, 2008). Increasing consumer demand for quality, safety, variety, seasonal availability and consistency are creating opportunities as well as possible barriers for Indian small and marginal mango farmers. Some of the major issues restricting the international trade and domestic transport of mango fruits are fruit fly infestation, disease incidence, sap burn, non-uniform ripening, chilling injury development during cold storage, etc. (Sivakumar *et al*., 2011) and pesticide residue. For managing fruit fly and anthracnose (important storage disease), apart from implementing good agricultural practices (GAPs) in field, postharvest disinfestation/ quarantine treatments are mandatory for international exports. Hot water treatment (HWT) is one among many quarantine treatments used for mango exports. HWT is a highly efficient, non-chemical, environment friendly and low-cost method (Jacobi *et al*., 1995; Anwar and Malik, 2007), which can also be adapted in local markets for inter-state transportation, aiming major Indian markets.

There are recommended time-temperature combinations to disinfect mangoes from fruit fly infestation and anthracnose infection. Heat treatments disinfect the commodity by diminishing fruit fly eggs and maggots (Paul and Chen, 2000). When mango fruits are subjected to thermal treatments, the storage life may be further reduced as heat treatments were reported to enhance the ripening process. Hence, it is significant to know how the application of these thermal treatments at recommended levels affects the quality and storage life of mango fruits. The present investigation reveals, whether particular HWTs (quarantine and disinfection treatments) affect the quality and shelf life of mango cv. Banganapalli when stored under ambient conditions.

MATERIALS AND METHODS

The cv. Banganapalli fruits of green mature stage were harvested and procured from mango orchards of ICAR-IIHR and transported carefully to the laboratory. Fruits were sorted to discard damaged ones and uniform sized and matured fruits were selected. Fruits were separated into four lots, three for HWTs and one as control (T_4). Different HWTs *viz*., T_1: 48°C for 60 min (recommended quarantine HWT for control of fruit fly), T_2: 55°C for 10 min (recommended HWT for control of anthracnose disease) and T_3: a combination treatment of 48°C for 60 min followed by 55°C for 10 min (to control both fruit fly and anthracnose) were used. The experiments were conducted in a rectangular batch type hot water treatment plant with a capacity of 500 kg/batch, developed at ICAR-IIHR. Hot water treated fruits and control fruits (water washed and air-dried) were packed in corrugated fibre board (CFB) boxes with three replications, each containing approximately 4 kg fruits, and stored at room temperature (ambient temperature: 28.1° to 32.2°C with 45-50% relative humidity).

Measurement of physiological and biochemical parameters

Respiration rate was recorded using Checkmate O_2/ CO_2 analyzer and expressed as mg CO_2/ kg/ h and ethylene evolution was measured using ethylene analyzer and expressed as μl C_2H_4/ kg/ h (Rao and Rao, 2008), taking five fruits as five replications per treatment. Physiological loss in weight (PLW) was calculated cumulatively and expressed as percentage. Five fruits were selected at random from each treatment for quality attributes analysis. The pulp was extracted from fruits, grinded in a mixer grinder and then homogenized (specific quantity required for individual parameters) using IKA T25 digital ultra Turarax homogenizer before analysis. TSS was measured using hand refractometer calibrated to 25°C (Erma Inc., Tokyo, Japan). Parameters like acidity (%), ascorbic acid (mg/100 g) and sugars (%) were estimated using standard methods of analysis (AOAC, 2000). Five gram of mango pulp was grinded in pestle and mortar using a solution of petroleum ether and acetone (3:2) along with acid washed sand to extract the carotenoid pigments and the OD values were read in spectrophotometer at 452 nm using petroleum ether-acetone solution as blank. Total carotenoid content was then calculated with reference to the standard curve prepared with β-carotene and expressed as μg/100 g pulp. Total phenolic content in the pulp was determined by the method of Singleton *et al*. (1999) and was expressed as milligram of gallic acid equivalent per 100 g of fresh weight (mg GAE/100 g FW). Total antioxiant capacity was determined in terms of FRAP (ferric reducing antioxidant power), using the method of Benzie and Strain (1996) and values were expressed as mg acetic acid equivalent (mg AAE)/100g FW.

Statistical analysis: The effects of different treatments over the variables were evaluated by two-way analysis of variance based on a completely randomized design. Software WINDOSTAT 9.3 version was employed to analyze the analysis of variance at 5% significance level and statistical significance of differences between the mean.

RESULTS AND DISCUSSION

Respiration rate of all HW treated fruits was significantly higher than that of control fruits (Fig. 1). Heat treatment might have accelerated the physiological metabolism and hastened ripening in these fruits, which was slow in control. A hot water treatment of 54°±1°C for 5 minutes in Alphonso fruits accelerated ripening and resulted in higher respiratory climacteric (Laksminarayana, *et al*., 1974). At the last day of reading, highest respiration rate was observed in the combination treatment. The effect of temperature on the respiration rate can be directly related to chemical reactions where the rate of reaction increases exponentially with an increase in temperature (Wills *et al*., 1989). Ethylene production rate of hot water treated fruits and control fruits were measured upto 1 week under ambient condition (Fig. 2). Ethylene peak was seen on the sixth day, where control fruits showed a highest value followed by 48°C for 60 min + 55°C for 10 min, 55°C for 10 min and 48°C for 60 min treatments. Among heat treatments, combination treatment had highest ethylene production rate and quarantine HWT recorded lowest. Highest ethylene production in control fruits can be attributed to early onset of diseases like anthracnose and soft rot during storage, which was merely present in HW treated fruits. Yimyong *et al*. (2011) reported similar results in room temperature ripening of HW treated mangoes after low temperature storage. HWT eliminated ripening related ethylene rise and suppressed ethylene

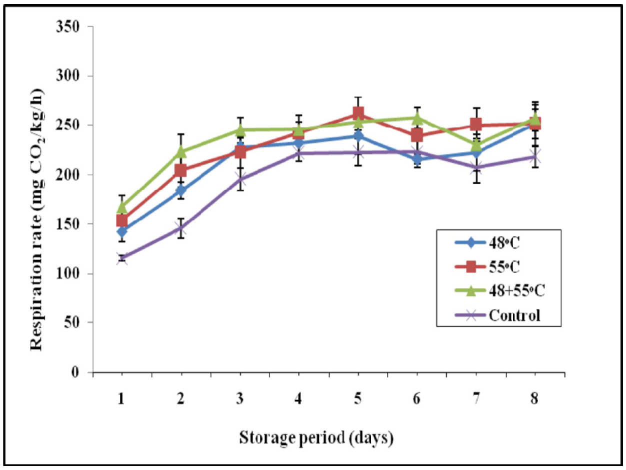

Fig. 1 : Effect of hot water treatments on respiration rate of mango cv. Banganapalli stored at RT

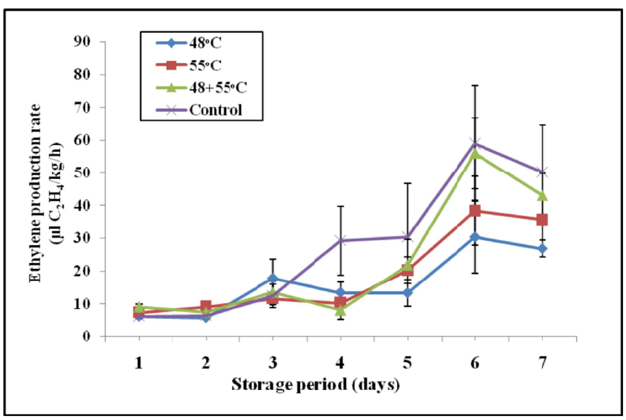

Fig. 2 : Effect of hot water treatments on ethylene production rate (µl C_2H_4/kg/h) of mango cv. Banganapalli stored at ambient temperature

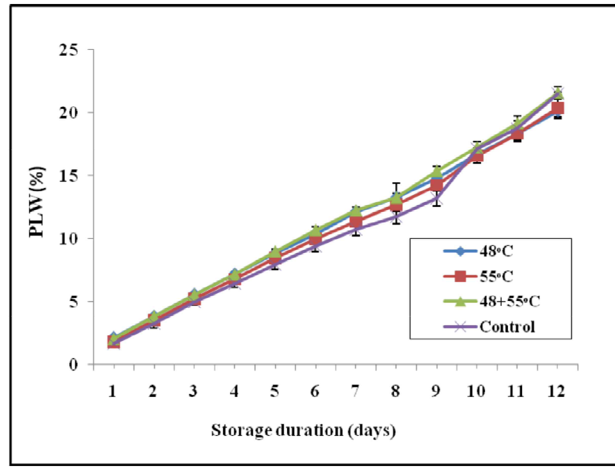

Fig. 3 : Effect of hot water treatments on physiological loss in weight of mango cv. Banganapalli stored at ambient temperature

production during subsequent storage at ambient temperature. PLW of fruits recorded upto 12 days of storage has been shown in Fig. 3. There was a gradual increase in fruits' PLW with storage duration, irrespective of the treatments. Initially, the loss in weight was higher in hot water treated fruits. This might be attributed to the stress developed in those fruits after subjected to heat treatment followed by ambient storage Further, the respiration rates of HW treated mangoes were also higher as depicted in Fig.1. PLW occurs in fruits due to many reasons, where membrane disruption associated higher rate of transpiration and water loss being one among them. The weight loss also depends on the temperature and duration of heat treatment (Perini *et al.*, 2017; Vilaplana *et al.*, 2018). After 9 days, the PLW in control fruits rapidly increased and at the end of storage highest PLW was observed in control fruits and 48°C for 60 min + 55°C for 10 min treatment fruits. More damage due to secondary disease development was seen in control fruits at the end of storage. HWT effectively reduced disease and pest development in treated fruits and maintained marketability even after 1 week. HWT combined with inorganic salts solution dips effectively reduced disease incidence and enhanced quality and storability of fruits till consumer end (Dessalegn *et al.*, 2013). Combination treatment, on the contrary, might have suffered more heat stress, leading to surface scald/ heat injury, providing inoculum for the development of diseases and hence, had maximum weight loss among HWTs.

Table 1 represents the changes in chemical attributes *viz.*, TSS, acidity, ascorbic acid and total sugars with respect to the treatments. TSS was more and acidity was less in HWTs, when compared to control. This is because, HW treated fruits ripened faster than that of control resulting in higher TSS during initial storage period. There was no negative effect on the ascorbic acid content of treated mango fruits. Ascorbic acid was seen highest in T_3 and T_1. Being most unstable vitamin, ascorbic acid content is affected by pre and post harvest treatments, heat treatments, storage duration *etc.* (Khader and Lee, 2000). In this experiment, ascorbic acid content was maintained in HWTs and during storage duration. It is the length of high temperature exposure during storage which may cause the loss of vitamin C and high temperature during HW treatment is only for shorter duration and so there was minimum loss of vitamin C. Studies

Table 1 : Effect of different hot water treatments on TSS, acidity, ascorbic acid, total sugar of mango cv. Banganapalli stored at ambient temperature

Treatment	TSS (°B)			Mean (T)	Acidity (%)			Mean (T)	Ascorbic acid (mg/100 g)			Mean (T)	Total sugars (%)			Mean (T)
	5 days	7 days	10 days		5 days	7 days	10 days		5 days	7 days	10 days		5 days	7 days	10 days	
T_1: 48°C for 60 min	20.67	21.67	21.60	21.31	0.47	0.33	0.25	0.35	3.20	5.60	9.47	6.09	14.89	13.78	15.08	14.59
T_2: 55°C for 10 min	21.53	22.07	19.87	21.16	0.54	0.34	0.29	0.39	3.27	5.13	6.73	5.04	12.68	16.47	15.31	14.82
T_3: 48°C for 60 min + 55°C for 10 min	22.13	21.27	20.53	21.31	0.53	0.42	0.32	0.42	4.27	6.73	10.33	7.11	11.51	14.18	15.89	13.86
T_4: Control (without treatment)	17.83	19.87	19.47	19.06	0.63	0.53	0.50	0.56	3.87	5.60	7.00	5.49	12.84	15.05	15.98	14.62
Mean (D)	20.54	21.22	20.37		0.54	0.41	0.34		3.65	5.77	8.38		12.98	14.87	15.56	
	T	D	TxD		T	D	TxD		T	D	TxD		T	D	TxD	
F test	**	**	**		**	**	**		**	**	**		**	**	**	
S.E.m±	0.23	0.27	0.47		0.01	0.01	0.02		0.18	0.20	0.35		0.18	0.20	0.35	
CD at 5%	0.68	0.79	1.37		0.03	0.03	0.06		0.52	0.60	1.03		0.52	0.60	1.04	

Table 2 : Effect of different hot water treatments on total carotenoid content, total phenols and total antioxidant capacity of mango cv. Banganapalli stored at ambient temperature

Treatment	Total carotenoid content (µg/100g)			Mean (T)	Total phenols (mg GAE/100g)			Mean (T)	Total antioxidant capacity (mg AAE/100g)			Mean (T)
	5 days	7 days	10 days		5 days	7 days	10 days		5 days	7 days	10 days	
T_1: 48°C for 60 min	1197.9	2228.9	2139.7	1863.8	42.45	40.46	40.65	41.19	42.81	40.64	39.20	40.88
T_2: 55°C for 10 min	1236.7	2206.1	2368.5	1937.1	41.48	39.93	41.19	40.87	41.62	40.06	38.01	39.90
T_3: 48°C for 60 min + 55°C for 10 min	991.7	1674.8	2242.8	1636.5	40.54	37.42	42.66	40.20	37.63	36.07	34.31	36.00
T_4: Control (without treatment)	1261.0	2063.0	2190.5	1838.2	40.43	38.24	34.08	37.58	37.12	39.26	36.98	37.79
Mean (D)	1178	2043.2	2235.4		41.22	39.01	39.64		39.80	39.01	37.12	
	T	D	TxD		T	D	TxD		T	D	TxD	
F test	**	**	**		**	**	**		**	**	**	
S.E.m±	43.57	50.31	87.14		0.57	0.66	1.14		0.23	0.27	0.46	
CD at 5%	127.18	146.85	254.35		1.66	1.91	3.31		0.67	0.78	1.35	

(Djioua *et al.*, 2009) reported the positive correlation between heat treatment and ascorbic acid content, stating, heat treatment did not affect but also maintained the ascorbic acid content.

HWTs maintained the total sugars in fruits during storage. Total sugars were highest in T_2 and lowest in T_3, which is the combination treatment (Table 1). Increased exposure to the heat in T_3 might have denatured the enzymes responsible for the synthesis of sugars. Papaya when immersed in hot water at 49°C for 90 min and 120 min acquired minimum sugar content due to the reduction of xylanal and polygalacturonase activity by reducing their synthesis (Benjamin *et al.*, 2018).

Other important bio-chemical parameters on which the effect of HWTs studied includes total carotenoids, phenols and antioxidant capacity (Table 2). Total carotenoids were higher in T_2, followed by T_1 and then T_4. Here, the combination treatment, T_3 recorded minimum carotenoids, though it had a higher peel colour. There was an elevated outcome on total phenols and antioxidant capacity in HWTs than that of control. Less antioxidant activity was seen in T_3. The total antioxidant activity, levels of phenolic compounds and ascorbic acid were higher in heat treated-pomegranate (Mirdehghan *et al.*, 2005) and strawberries due to the stimulation of protective enzymes against oxidation (Viente *et al.*, 2006).

CONCLUSION

Hot water treatment is one of the promising methods to prevent fruit fly disinfestations and decay in mango during storage, though, there is concern regarding its effect on fruits' storage life and quality. In the present experiment, HWTs did not negatively affect the physiological and biochemical attributes. Recommended HWTs for fruit fly and anthracnose control, when applied alone enhanced the biochemical quality viz., higher sugar content and lower acidity, higher carotenoid content, phenolics and antioxidant capacity compared to control fruits. The combination of these treatments did not give any positive results in terms of quality. Standalone HWT can be recommended as a potential, safe and non-chemical treatment to manage diseases, fulfil quarantine requirements, improve quality and storage life, aiding to quality fruits supply in local as well as international markets.

ACKNOWLEDGMENT

The financial support by Government of India, Department of Science and Technology, as DST-INSPIRE fellowship, is gratefully acknowledged by the first author. Authors also acknowledge ICAR-IIHR for availing the laboratory facility.

REFERENCES

Anwar, R. and Malik, A. U. 2007. Hot water treatment affects ripening quality and storage life of mango (*Mangifera indica* L.). *Pak. J. Agric. Sci*. **44**: 304-311.

Benjamin, Y., Clement, Y. B., Edith, N. K. and Kablan, T. 2018. The effect of thermal treatment (49°C-90 min) coupled with storage at 15°C on the infection rate, physicochemical and nutritional characteristics of the papaya (*Carica papaya* L. var Solo 8). *Int. J. Adv. Res. Boil. Sci*., **5**(5): 1-11.

Benzie, I.F. and Strain, J.J., 1996. The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the FRAP assay. *Anal. Biochem*., **239**(1): 70-76.

Dessalegn, Y., Ayalew, Y. and Woldetsadik, K. 2013. Integrating plant defense inducing chemical, inorganic salt and hot water treatments for the management of postharvest mango anthracnose. *Postharvest Biol. Technol*., **85**: 83-88.

Djioua, T., Charles, F., Lopez-Lauri, F., Filgueiras, H., Coudret, A., Freire, M., Ducamp-Collin, M. and Sallanon, H. 2009. Improving the storage of minimally processed mangoes (*Mangifera indica* L.) by hot water treatments. *Postharvest Biol. Technol*, **52**(2): 221-226.

Hoa, T. T., Ducamp, M. N., Lebrun, M. and Baldwin, E. A., 2002. Effect of different coating treatments on the quality of mango fruit. *J. Food Qual*., **23**: 471-486.

Jacobi, K. K., Wong, L. S. and Giles, J. E. 1995. Effect of fruit maturity on quality and physiology of high humidity hot air treated 'Kensington' mango (*Mangifera indica* L.). *Postharvest Biol. Technol*., **5**: 149-159.

Khader, A. A. and Lee, S. K. 2000. Preharvest and postharvest factors influencing vitamin C content of horticultural crops. *Postharvest Biol. Technol*., **20**: 207-220.

Lakshminarayana, S., Krishnaprasad, C. A. and Shetty, M. S. 1974. Hot water treatment to regulate ripening and reduce spoilage of Alphonso mangoes. *J. Hortic. Sci. Biotechnol.*, **49**: 365-371.

Mirdehghan, S. H., Rahemi, M., Serrano, M., Guillea, F. N., Martianez-Romero, D. and Valero, D., 2006. Prestorage heat treatment to maintain nutritive and functional properties during postharvest cold storage of pomegranate. *J. Agric. Food Chem.*, **54**: 8495-8500.

Paul, R. E. and Chen, N. J. 2000. Heat treatment and fruit ripening. *Postharvest Biol. Technol.*, **21**: 21-37.

Perini, M. A., Sin, I. N., Reyes-Jara, A. M., Lobato, E. G., Civelloand, P. M. and Martínez., G. A. 2017. Hot water treatments performed in the base of the broccoli stem reduce postharvest senescence of broccoli (*Brassica oleracea* L. Varitalica) heads stored at 20°C. LWT- *Food Sci. Technol.*, **77**: 314-322.

Rao, D. V. S. and Rao, K. P. G. 2008. Controlled atmosphere storage of mango cultivars 'Alphonso' and 'Banganapalli' to extend storage-life and maintain quality. *Postharvest Biol. Technol.*, **83**(3): 351-359.

Singleton, V.L., Orthofer, R. and Lamuela-Raventós, R.M. 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. In: *Methods in enzymology*. Academic Press., **299**: 152-178.

Sivakumar, D., Jiang and Yahia, E. M. 2011. Maintaining mango (*Mangifera indica* L.) fruit quality during the export chain. *Food Res. Int.*, **44**: 1254-1263.

Vicente, A. R., Martý´nez, G. A., Chaves, A. R. and Civello, P. M. 2006. Effect of heat treatment on strawberry fruit damage and oxidative metabolism during storage. *Postharvest Biol. Technol.*, **40**: 116-122.

Vilaplana, R., Hurtado G. and Valencia-Chamorro, S. 2018. Hot water dips elicit disease resistance against anthracnose caused by *Colletotrichum musae* in organic bananas (*Musa acuminata*). LWT - *Food Sci. Technol.*, **95**: 247-254.

Wills, R. B. H., McGlasson, W. B., Graham, D., Lee, T. H. and Hall, E. G. 1989. Post-harvest. An introduction to the Physiology and Handling of Fruits and Vegetables, 3rd edition. AVI New York.

Yimyong, S., Datsenka, T. U. and Handa, A. K. 2011. Hot water treatment delays ripening associated metabolic shift in 'Okrong' mango fruit during storage. J. *Amer. Soc. Hort. Sci.*, **136**(6): 441-451.

(Received : 13.01.2023; Revised : 27.03.2023; Accepted 31.05.2023)