RESEARCH ARTICLE

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EFFICACY OF CHEMICALS AND HOT WATER TREATMENTS ON QUALITY AND SHELF LIFE OF AMRAPALI VARIETY OF MANGO

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ABSTRACT

An experiment was conducted to evaluate the effect of hot water and chemicals on the quality and shelf life of Amrapali variety of mango at Agriculture and Forestry University, Rampur, Chitwan, Nepal. The experiment was laid out in completely randomized design with 6 treatments and 4 replications. Physiologically matured mango fruits (200±20 g) were treated with distilled water for 10 minutes, hot water @ 50°C for 10 minutes, hot water @ 55°C for 10 minutes, carbendazim solution @ 0.1% for 10 minutes and Sodium hypochlorite solution @ 100 ppm for 2 minutes. The untreated fruits were considered as control treatment. The highest total soluble solid (18.15°Brix), the lowest physiological loss in weight (24.20%) and the lowest spoilage loss (42.05%) were observed in fruits treated with hot water at 55°C. Therefore, the post-harvest treatment of mango fruits with hot water at 55°C for 10 minutes was found to be effective for maintaining the quality and shelf life of mango.

1. INTRODUCTION

Mango is a king of fruits and is is a popular tropical fruit of Nepal due to its attractive aroma, flavor, color, nutritional value and diverse use (Mathiazhagan *et al*., 2022). Mango is the leading fruit of Nepal with area, production and productivity of 43,688 ha, 466,266 ton and 10.67 ton/ha respectively (MoALD, 2022). The contribution of mango in agriculture gross domestic product (AGDP) was 2.51% in the fiscal year 2021/22. The demand of mango is increasing day by day and to fulfill this demand, 13.65 million metric tons of fresh mango fruits has been imported from India and other countries in the year 2021 (FAO, 2022). This could due to low production, high post-harvest loss and seasonal nature of production. Mango fruit is highly perishable in nature with very short shelf life ranging from 4 to 8 days at normal room temperature and 2-3 weeks in cold storage at 13ºC, but it also varies among the cultivars (Carrillo *et al*., 2000). After harvest, various physiological and biochemical changes occur in the mango fruit causing significant amount of qualitative and quantitative changes during storage and transportation (Bambalele *et al*., 2021). High moisture content, soft texture and susceptibility to various pathogens are limiting factors of longer shelf life (Makka *et al*., 2019). The high post-harvest loss of mango is mainly associated with the harvesting technique, post-harvest handling and microbial spoilage, thus, affecting its quality and marketable period (Zheng *et al*., 2012). In Nepal, post-harvest loss of mango varies between 20 to 30% (Bhattarai, 2018).

Chemicals like carbendazim, sodium hypochlorite, benomyl, potassium permanganate, methyl cyclopropane and non-chemical post-harvest treatments like botanical extracts, polythene film and edible coatings are mostly used to maintain fruit quality

during handling of the mango fruit (Bambalele *et al*., 2021). However, existing post-harvest technologies are expensive and may not be accessible and adaptable to the Nepalese context (Mahajan *et al*., 2014). Among several diseases, anthracnose (*Colletotrichum gloeosporioides*) is one of the major post-harvest diseases in all mango producing regions of the world causing significant post-harvest loss (Dodd *et al*., 1997). Synthetic fungicides (benomyl, prochloraz, carbendazim) and chemical preservatives (1-MCP, nitric oxide, salicylic acid, GA3) are extensively used to retard respiration rate, inhibit ethylene biosynthesis, retain firmness, delay fruit ripening and control microbial spoilage (Coates *et al*., 1993; Hong *et al*., 2014; Banerjee *et al*., 2015; Razzaq *et al*., 2016). However, the growing concerns of public over the indiscriminate use of synthetic chemicals, associated health risk, potential environmental hazards and possibility of occurrence of resistant pathogen strains forced to move mango industry into safer alternatives (Yao and Tian, 2005; Dessalegn *et al*., 2013; Bambalele *et al*., 2021). Thus, there is an urgent need to develop low cost, accessible, environment friendly and non-chemical alternatives. Application of inorganic salts, plant extracts, edible coatings and heat treatment are other promising strategies to increase the shelf life of the mango fruit (Kumlachew *et al*., 2014; Bambalele *et al*., 2021). Controlled atmosphere, pulsed electric field and Gaseous ozone are some of the emerging and potential technologies in the mango fruit industry (Bambalele *et al*., 2021). Among different non-chemical treatments, hot water treatment has gained wide international interest in quality maintenance and disease control (Kumah *et al*., 2011; Obsa *et al*., 2014). Mango initially free from disease at harvest develop anthracnose as fruit ripens is the major cause of post-harvest loss (Dodd *et al*., 1997), which can be controlled by dipping in hot water (Simmonds, 2005). Reducing post-harvest losses and extending the shelf life are the key issue that needs to be addressed by using relevant technologies for reliable and long-term supply of fresh mango fruits in Nepalese market. Therefore, the present study was conducted with the objective to analyze the efficacy of chemicals and hot water treatment on quality and shelf life of mango under Chitwan condition of Nepal.

2. MATERIALS AND METHODS

2.1 Description of the experiment site

This experiment was conducted at the horticulture laboratory of Agriculture and Forestry University, Rampur, Chitwan, Nepal, during July 2018. Geographically, the experimental site and the orchard from where mangoes are collected are located in the Terai region at 27° 40' N latitude and 84° 19' E longitudes and at an elevation of about 228 masl. The sample fruit collection area represented the area of commercial mango production in Nepal. The average temperature and relative humidity of laboratory during the research period was 29.4° C and 77.25% respectively.

2.2 Selection of variety and harvesting

Amrapali variety was selected from the commercial mango orchard of Chitwan, Nepal which is categorized as mid to late season variety, regular bearer, precious, best yielder and ripens during first to second week of July. Selected fruits were 200±20 gm size. Uniform sized, physiologically matured fruits were harvested with the help of pole harvester during the morning period after the dew has evaporated. They were collected in plastic crates and taken to experimental site located 100 m away from the orchard. Brushed, wounded and diseased mango fruits were sorted out.

2.3 Design of experiment

The experiment was carried out using Completely Randomized Design with six treatments and four replications. Each experimental unit consists of 13 fruits, of which 8 were subjected to destructive testing, while the remaining 5 were preserved for non-destructive analysis.

Treatment details

T_1: Control (no dipping)

T_2: Distilled water dipping for 10 minutes

T_3: Hot water treatment @ 50°C for 10 minutes

T_4: Hot water treatment @ 55°C for 10 minutes

T_5: Carbendazim solution @ 0.1% for 10 minutes

T_6: Sodium hypochlorite solution @ 100 ppm for 2 minutes

2.4 Method of treatments application

Selected fruits were kept for 10 minutes in hot water bath for hot water treatment. For chemical treatment, required amount of chemical were weighed/measured to make the required concentration of said chemicals using distilled water. 0.1% of carbendazim solution was prepared by mixing 1 gm of carbendazim in 1 litre of distilled water and 100 ppm sodium hypochlorite (NaOCl) solution was prepared by mixing 100 mg of sodium hypochlorite in 1 litre of distilled water. Fruits were kept separately

(replication wise) in a perforated plastic tray.

2.5 Observation taken

The observation on different qualitative and quantitative parameters was recorded at three days interval. Total soluble solids (TSS) content measured by using analogue hand held refractometer (EMRA Inc., Tokyo Japan) and expressed in terms of °Brix. Titratable acidity (TA) was determined by titration of mango juice against 0.1 N NaOH solution and expressed as percent (%) malic acid. TSS:TA ratio was determined by dividing the TSS with their corresponding TA values. Ascorbic acid contents were determined by titrating 5 ml of mango juice aliquot (obtained from 10 ml juice and 90 ml of 0.4% oxalic acid) against 2,6-dichlorophenolindophenol and expressed as mg 100 ml^{-1} of fruit juice (Ali *et al*., 2016). Fruit weight was measured at 3 days interval by using electronic digital weighing balance and physiological loss in weight was estimated as per the procedure of Hasan *et al*. (2020) and expressed in percentage. Spoilage loss was determined based on fruit skin defects (Holmes *et al*., 2009) and disease incidence (Amin *et al*., 2007). Shelf life of mango fruit was a period of time which started from harvesting and extends up to the start of rotting of fruits (Bevery, *et al*., 1992). Shelf life of mango fruits were calculated by counting optimum marketing and eating qualities based on physiological loss in weight and spoilage loss.

2.6 Statistical analysis

The collected data were compiled and entered into Microsoft Excel (2016) and analysis was carried out by using software R Studio (version 3.0.3). Mean separation was carried out using Fisher's least significant difference (LDS) at 0.05 level of significance ($P < 0.05$).

3. RESULTS AND DISCUSSION

Analysis of variance showed that significant difference was observed among different treatments with respect to TSS, TA, Ascorbic acid content, TSS/TA ratio, pulp pH, physiological loss in weight, spoilage loss and shelf life.

3.1 Total soluble solids

The highest TSS content (18.15°Brix) was observed in 9th days after treatment (DAT) with fruits treated with hot water @ 55°C. At 12 DAT, fruits treated with hot water @ 55°C recorded the highest TSS (17.82° Brix) which was statistically at par with hot water @ 50°C. The lowest TSS (14.0° Brix) was observed in fruits treated with NaOCl which was statistically at par with fruits dipped in distilled water. Result of TSS/TA ratio indicated that the highest TSS/TA ratio (190.04) was observed with hot water treatment @ 50°C which was statistically similar with hot water treatment @ 55°C, whereas, the fruits dipped with distilled water showed the lowest (97.67) TSS/TA ratio (Table 1).

During the storage period, TSS content and TSS/TA ratio was increased with advancement of storage period. Increasing trend of TSS was due to hydrolysis of stored polysaccharides into soluble sugar and conversion of organic acid into sugars (Wasker *et al*., 1999). This result was supported by the findings of Rathore *et al*. (2007), who found that sharp increase in TSS content from 10 to 16.2°Brix until 6th day of storage and gradually decreased to 5.1°Brix during 15th day of storage. However, TSS content increased continuously and acidity decreased continuously. The cellulose and pectin present in mango fruits are hot water soluble and are hydrolyzed to simple sugars after hot water treatment which might be the reason of highest TSS in hot water treated fruits.

Table 1. Effect of chemicals and hot water treatments on TSS content and TSS/TA ratio of Amrapali variety of mango

Treatments	TSS (°Brix)				TSS/TA			
	3 DAT	6 DAT	9 DAT	12 DAT	3 DAT	6 DAT	9 DAT	12 DAT
Control	14.32^{abc}	16.85^{abc}	16.90^{ab}	15.95^{ab}	16.76^{b}	37.87^{b}	60.32^{b}	98.26^{b}
Distilled water for 10 minutes	11.72^{c}	14.80^{cd}	14.82^{b}	14.62^{b}	13.70^{b}	32.00^{b}	54.86^{b}	97.67^{b}
HWT @ 50°C for 10 minutes	15.88^{a}	17.35^{ab}	17.52^{ab}	17.45^{a}	32.62^{a}	66.67^{a}	123.86^{a}	190.04^{a}
HWT @ 55°C for 10 minutes	15.55^{a}	18.07^{a}	18.15^{a}	17.82^{a}	34.71^{a}	74.09^{a}	129.96^{a}	189.84^{a}
Carbendazim @ 0.1% for 10 minutes	12.85^{bc}	14.47^{d}	16.07^{ab}	16.05^{ab}	19.86^{b}	39.73^{b}	73.76^{b}	107.00^{b}
NaOCl @ 100 ppm for 2 minutes	14.65^{ab}	15.35^{bcd}	15.52^{ab}	14.00^{b}	18.87^{b}	44.26^{b}	64.43^{b}	101.74^{b}
Mean	14.16	16.15	16.49	15.98	22.75	49.1	84.53	130.76
LSD (P=0.05)	2.69^{*}	2.13^{**}	3.17^{*}	2.2^{*}	6.66^{*}	13.81^{*}	32.04^{*}	46.08^{*}
CV%	8.46	5.86	8.59	6.1	13.03	12.52	16.87	15.68

Means in a column followed by the same letter do not differ according to Fisher's least significant difference (LSD) at 0.05 level ($P < 0.05$). * represents significant ($P \leq 0.05$), ** represents highly significant ($P \leq 0.01$), CV is the coefficient of variation.

Due to the presence of multi OH group around polysaccharides, the solvent (hot water) creates solvating environment around polymer chain keeping polysaccharide molecules away from each other (Guo *et al*., 2017). This result was supported by Djioua *et al*. (2009) also. Whereas, later during storage, slight decreased in TSS content was observed in all treatments as a fact that reducing sugar are converted back into polysaccharides (Anwar and Malik, 2007).

3.2 Titratable acidity and ascorbic acid (vitamin C) content

During the observation period, significant difference was seen among the treatments, highest TA (0.164 %) was observed in untreated fruits and the lowest TA (0.094 % & 0.096 % respectively) was observed in fruits treated with hot water @ 50°C and 55°C. Ascorbic acid content decreased gradually among all treatments along the advancement of storage period and was found highest (24.33 mg) with fruits treated with hot water @ 55°C during the course of storage period and the lowest (20.56 mg) with untreated fruits at 12 DAT (Table 2).

Continuous decrease of titratable acidity was due to the action of enzyme citric acid glyoxalase which cause the degradation of citric acid (Rathore *et al*., 2007). The decreasing trend in ascorbic acid content was due to utilization of organic acids as a respiratory substrate during ripening, limited supply of sugar (Vala and Bhatt, 2002) and the conversion of L-ascorbic acid into dehydro-ascorbic acid upon the action of enzyme ascorbinase (Mapson, 1970). This result is similar with the findings of Wills *et al*. (2007). But preservation of ascorbic acid content in fruits treated with hot water was due to the fact that ascorbate is synthesized through Smirnoff-Wheeler (SW) pathway in fruits from D-glucose through series of intermediate products (Bulley *et al*., 2009; Mellidou *et al*., 2012), and D-galacturonate pathway which utilize pectin as substrate (Di Matteo *et al*., 2010). As in both case hydrolysis of polysaccharides caused due to hot water treatment plays important role in providing substrate for ascorbic acid synthesis. This result is further supported by Srinivasan *et al*. (1973).

Table 2. Effect of chemicals and hot water treatments on titratable acidity (%) and ascorbic acid content (%) of Amrapali variety of mango.

Treatments	TA (%)				Ascorbic acid (mg/100g pulp)			
	3 DAT	6 DAT	9 DAT	12 DAT	3 DAT	6 DAT	9 DAT	12 DAT
Control	0.854^{a}	0.448^{ab}	0.285^{a}	0.164^{a}	33.44^{b}	28.43^{c}	25.20^{c}	20.56^{c}
Distilled water for 10 minutes	0.854^{a}	0.465^{a}	0.268^{a}	0.154^{a}	33.12^{b}	28.88^{c}	25.96^{bc}	21.48^{bc}
HWT @ 50°C for 10 minutes	0.490^{c}	0.262^{de}	0.142^{b}	0.094^{b}	42.19^{a}	34.39^{a}	28.19^{ab}	24.19^{ab}
HWT @ 55°C for 10 minutes	0.452^{c}	0.247^{e}	0.142^{b}	0.096^{b}	44.38^{a}	36.67^{a}	29.19^{a}	24.33^{a}
Carbendazim @ 0.1% for 10 minutes	0.654^{b}	0.367^{bc}	0.221^{a}	0.151^{a}	34.66^{b}	29.43^{bc}	24.90^{c}	22.03^{abc}
NaOCl @ 100 ppm for 2 minutes	0.779^{a}	0.352^{cd}	0.241^{a}	0.138^{a}	40.31^{a}	33.19^{ab}	26.31^{bc}	23.16^{abc}
Mean	0.680	0.357	0.217	0.133	38.02	31.83	26.63	22.62
LSD (P=0.05)	0.1^{**}	0.09^{*}	0.07^{*}	0.03^{*}	5.44^{*}	3.99^{*}	2.73^{*}	2.84^{*}
CV%	6.77	11.33	13.57	9.61	6.37	5.58	4.56	5.59

Means in a column followed by the same letter do not differ according to Fisher's least significant difference (LSD) at 0.05 level ($P < 0.05$). * represents significant ($P \leq 0.05$), ** represents highly significant ($P \leq 0.01$), CV is the coefficient of variation.

3.3 Pulp pH

The increasing trend of pH was seen along the extension of storage period up to 9th day of storage. A slight decrease in pH was noticed in distilled water, hot water treatment @ 50°C and 55°C and 0.1% carbendazim while pH of NaOCl treated fruits continuously increased during the storage period and pH of control became static (Table 3). Higher retention of pH in fruits treated with hot water was due to the slower rate of degradation of fruit constituents like ascorbic acid resulting in increased pH (Ghosh *et al*., 1981). Similar results were reported by Prasad and Mali (2000).

Table 3. Effect of chemicals and hot water as post-harvest treatments on pulp pH of Amrapali variety of mango.

Treatments	Pulp pH			
	3 DAT	6 DAT	9 DAT	12 DAT
Control	4.42^{ab}	4.58^{ab}	5.45	5.45^{ab}
Distilled water for 10 minutes	3.49^{c}	4.14^{b}	5.11	4.91^{c}
HWT @ 50°C for 10 minutes	4.50^{a}	5.15^{a}	5.99	5.57^{a}
HWT @ 55°C for 10 minutes	4.86^{a}	5.12^{a}	5.98	5.75^{a}
Carbendazim @ 0.1% for 10 minutes	4.51^{a}	4.26^{b}	5.91	5.65^{a}
NaOCl @ 100 ppm for 2 minutes	3.81^{bc}	4.35^{b}	5.00	5.05^{bc}
Mean	4.27	4.6	5.57	5.4
LSD (P=0.05)	0.63*	0.71*	NS	0.52*
CV%	6.6	6.86	8.11	4.27

Means in a column followed by the same letter do not differ according to Fisher's least significant difference (LSD) at 0.05 level (P < 0.05). NS represents non-significant, * represents significant (P≤0.05), CV is the coefficient of variation.

3.4 Physiological loss in weight

The result revealed that PLW was highest (32.62%) in distilled water dipped fruits which was statistically at par with control and NaOCl whereas, PLW was the lowest (24.20%) on hot water treatment @ 55°C.Spoiled fruits percent increased significantly after 6th days of storage in all treatments. During 12th DAT, the highest spoilage (69.20%) was observed in distilled water dipped fruits which was similar with control and NaOCl treated fruits. The lowest spoilage loss (42.05%) was recorded in hot water treated fruits @ 55°C (Table 4).

A significant increase in physiological loss in weight and increasing trend of spoilage loss was observed irrespective of the treatments as the storage period prolonged. The loss in weight was due to more loss of moisture as evapo-transpiration and respiration through uninterrupted atmospheric column (Reddy, 2015). The lower weight loss in hot water treated fruits attributed to slow breakdown of respiratory substrate due to inactivation of enzyme (Djioua *et al*., 2009). This result is supported by Vala and Bhatt (2002). Hot water treatment can effectively suppress the growth of pathogens, may disinfect the fruit surface and inhibit the latent infection, thereby improved the shelf life (Mansour *et al*., 2006; Shiesh *et al*., 2017). Additionally, hot water treatment act as an elicitor for the activation of the defensive response in harvested fruits (Huan *et al*., 2017).

Table 4. Effect of chemicals and hot water treatments on PLW and spoilage loss of Amrapali variety of mango

Treatments	WPLW (%)				Spoilage loss (%)			
	3 DAT	6 DAT	9 DAT	12 DAT	3 DAT	6 DAT	9 DAT	12 DAT
Control	8.23^{a}	17.52^{a}	23.61^{a}	32.33^{a}	0.00	12.18^{ab}	32.87^{a}	67.92^{a}
Distilled water for 10 minutes	8.41^{a}	17.30^{a}	21.08^{ab}	32.63^{a}	0.00	12.95^{a}	31.90^{a}	69.20^{a}
HWT @ 50°C for 10 minutes	6.63^{b}	13.41^{bc}	16.57^{c}	26.36^{b}	0.00	8.78^{c}	18.15^{b}	46.72^{b}
HWT @ 55°C for 10 minutes	6.42^{b}	12.75^{c}	15.34^{c}	24.20^{b}	0.00	9.25^{c}	17.95^{b}	42.05^{b}
carbendazim @ 0.1% for 10 minutes	6.25^{b}	15.95^{ab}	17.47^{bc}	29.00^{ab}	0.00	10.21^{bc}	23.96^{ab}	47.73^{b}
NaOCl @ 100 ppm for 2 minutes	7.46^{ab}	17.02^{a}	18.69^{bc}	32.45^{a}	0.00	10.06^{bc}	26.42^{ab}	65.09^{a}
Mean	7.23	15.66	18.79	29.5	0.00	10.57	25.21	56.45
LSD (P=0.05)	1.23*	2.98*	3.7*	5.46*	0.00	2.46*	9.44*	13.79*
CV%	7.61	8.47	8.76	8.24	0.00	10.36	16.67	10.87

Means in a column followed by the same letter do not differ according to Fisher's least significant difference (LSD) at 0.05 level (P < 0.05). * represents significant (P≤0.05), CV is the coefficient of variation.

3.5 Shelf life

Shelf life of mango fruits was significantly affected by different post-harvest treatments. Results revealed that the longest shelf life (14.25 days) of mango fruits was observed in the fruits treated with hot water @ 55°C. The shortest shelf life of 9.50 days was observed in the fruits dipped in distilled water for 10 minutes (Table 5). The longest shelf life of fruits treated with hot water was possibly due to the reduced rate of physico-chemical changes, reduced weight loss and minimal disease severity and the suppression of microbial growth (Hoque *et al., 2017*).

Table 5. Effect of chemicals and hot water treatments on Shelf life of Amrapali variety of mango

Treatments	Shelf life
Control	9.75[b]
Distilled water for 10 minutes	9.50[b]
HWT @ 50°C for 10 minutes	13.50[a]
HWT @ 55°C for 10 minutes	14.25[a]
carbendazim @ 0.1% for 10 minutes	13.50[a]
NaOCl @ 100 ppm for 2 minutes	10.00[b]
Mean	11.75
LSD (P=0.05)	1.33[**]
CV%	7.64

Means in a column followed by the same letter do not differ according to Fisher's least significant difference (LSD) at 0.05 level ($P < 0.05$). ** represents highly significant ($P \leq 0.01$), CV is the coefficient of variation.

4. CONCLUSION

The present study concluded that hot water treatment of mango fruits at 55°C was found to be effective for marinating quality and shelf life of mango due to its superior performance for most of the important post-harvest parameters (TSS, PLW, vitamin C, pH and spoilage loss). Considering the quality, consumer's preferences, environmental aspects and cost of application, the present result clearly indicated that the hot water treatment at 55°C can be alternative of synthetic chemicals in post-harvest management of mango.

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