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Effect of Modified Atmospheric Packaging on Physico-chemical Properties and Puncture Strength of Banarasi Langra Mango (*Mangifera indica*)

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ABSTRACT

Background: Mango (*Mangifera indica* L.), a perishable tropical climatic fruit, has a short post-harvest life. Modified atmospheric packaging is an efficient way to keep their quality safe during extended storage. This study aims to assess the efficacy of various combinations of gas concentrations under MAP.

Methods: Mature green mangoes were subjected to a hot water dip (40°C) for 30 min which was followed by packaging in polyethylene pouches under two different MAP gas concentrations and stored for 25 days at 10 and 15°C for physico-chemical analysis and texture profile analysis.

Result: Warm water dip (40°C) for 30 min was the most effective post-harvest storage condition, followed by packaging in poly bags under MAP gas combination, *i.e.*, O_2- 7%: CO_2- 50%. The keeping quality of 25 days was achieved significantly better than the control samples, which showed deterioration after 12 days of storage.

Key words: Carotenoid, Mango, Modified atmospheric packaging (MAP), Puncture strength, Shelf life.

INTRODUCTION

Mango (*Mangifera indica* L.) is a well-known tropical climatic fruit because of its sweet, delicious flavor and rich source of nutrients and various phytochemicals (Ntsoane *et al.* 2019). Mango is grown in over 88 countries, with India, China, Thailand, Indonesia and Mexico leading the way as commercial producers and can be cultivated in tropical and subtropical climates (Rodrigues *et al.* 2016). India uses an area of 2.31 million hectares for mango cultivation and produces 18.5 million tons, approximately 40% of total mango production worldwide (FAO, 2017). India has many mangoes such as 'Langra,' 'Alphonso,' 'Dashehari,' 'Chausa,' and 'Banganpalli. Mangoes ripen quickly within 3-9 days after detaching, when stored at room temperature, become prone to microbial growth and cause softening of tissues (Rastegar *et al.* 2019). To extend the shelf life of mango, these changes must be controlled by proper treatment (hot water treatment, refrigerated and gas storage, dipping in various chemical, oil and wax emulsions and appropriate post-harvest management (Kim *et al.* 2007).

The biggest challenge is being a highly perishable fruit that suffers from significant post-harvest losses of 30-40% (Lawson *et al.* 2019). Temperature, atmospheric composition, maturity and the physiological state of fresh produce all influence the shelf life of fruits; the slower rate of respiration results in a more extended storage ability of the packaged product. Respiration is a metabolic process that provides energy to plants' biochemical processes. Aerobic respiration is the oxidative breakdown of organic reserves to simpler molecules like CO_2 and H_2O, followed by the release of energy. MAP is the most successful method for retarding respiration and biochemical activities during storage. MAP is the replacement of a gas within a package for reducing deterioration and extending the shelf life of fruits and vegetables. The MAP effectively preserves both fresh and perishable foods. Mangoes packed under MAP show reduced weight loss and a more extended ripening period, extending the shelf life of fresh mangoes (Sothornvit and Rodsamran, 2010; Wilson *et al.* 2019).

The shelf-life of fruits and vegetables by using MAP depends on various factors like bacterial proliferation, organoleptic qualities, yeast and mold growth, color changes, fruit tissue decay and prevention of chilling injuries have been studied for an extensive range of minimally processed horticultural products. Increased CO_2 and decreased O_2 levels, which reduce respiration rate and prevent water loss, are the main factors that maintain mango

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quality in various film packaging (Tavassoli-Kafrani *et al.* 2020). The gaseous composition in MAP is influenced by factors such as packaging permeability and micro-perforations in the film (Gonzalez-Buesa *et al.* 2013). Recent reports suggested that low O_2 combinations should take care of fruit characteristics to avoid anaerobic respiration (Wilson *et al.* 2019). High O_2 concentrations degrade product quality by encouraging free radical generation, damaging plant tissues. Varela and Royals (2011) studied the physico-chemical aspects of Vallenato mango variety under MAP (packed in low density polyethylene) and used 3 different gas mixture combinations (3% O_2, 3% CO_2, 94% N_2; 4% O_2, 7% CO_2, 89% N_2; 5% O_2, 5% CO_2, 90% N_2) at 12°C. They reported that gas mixture 5% O_2, 5% CO_2, 90% N_2 keep the quality of mango variety safe for a longer time.

The Mango cv. Langra (Banarasi) cultivar is a mid-season cultivar native to Uttar Pradesh. It is the most popular variety in the local market due to its high quality but has a medium shelf life and poor storage quality. Thus, to extend the shelf life and maintain the biochemical quality of harvested mango fruits during storage, the current study aimed to assess the performance of the MAP technique in combination with a warm water dip and low-temperature storage for preserving the quality of Banarsi langra mangoes.

MATERIALS AND METHODS

Sample materials

Mangoes (*Mangifera indica*) of the cultivar *Langra (Banarasi)* were obtained from the orchards of "Department of Horticulture, Banaras Hindu University, Varanasi, India." Green mature mangoes (approximately 90-100 days), skin color: light green, shoulder portion: bulging, skin surface: smooth and having a homogenous size of 250±25 g were selected for this study.

Processing and packaging

Mangoes were sorted by hand, washed with water thoroughly and then kept at 10°C for 18 h. Mangoes were soaked in 40±2°C warm water for 30 min. The 30 min immersion time was chosen to disintegrate ethylene synthesizing enzymes (Lurie, 1998). Mangoes without warm water dip were used as control. Both treated and untreated mangoes were then cooled at 10°C (suitable temperature for packaging), washed and wiped clean. Uniformly sized fruits were selected and packaged in PA-PE polybags were made of polyamide 20 µm-polyethylene 70 µm with ethylene vinyl alcohol (EVA) sealant layer, total gauge (µm) 90±10% and weight per area (g/m^2) 82.2±10% respectively in a MAP unit (VAC-STAR* S 220 MP, Make: Switzerland) with two different gas compositions, namely A (O_2- 7% : CO_2- 50% : N_2- 43%) and B (O_2-15% : CO_2- 5% : N_2-80%). The headspace contents of gases in the packs were determined using a gas analyzer (CheckMate3, Make: PBI Dansensor, Denmark), inserting a small needle through a septum and closing the hole after the sample was taken. Mangoes packed under MAP (2 fruits in each polybag) were stored at 10 and 15°C for 25 days because fruits below 10-12°C suffer chilling injury.

Physico-chemical analysis

Stored samples were examined for physico-chemical analysis of every fifth-day interval for 25 days under MAP conditions. The results are an average of three replicates. Total weight loss during that storage interval was calculated as the difference between the initial and final mango weight, expressed in g. The total soluble solids (TSS) were determined using a refractometer (Model: RFM 970, Make: UK) according to Daramola and Asunni (2007) method. The AOAC (2000) standard methods were used to determine titratable acidity. The pH was measured using a digital pH meter (Orion 2 Star, Thermo Scientific) following the AOAC method. The Indophenol titration method determined the ascorbic acid (Ruck, 1963). Using the AOAC method (2000) at 436 nm, Carotene content using a spectrophotometer (UV-1800, Shimadzu, Kyoto, Japan). Carotenoids content was expressed as µg/g of β-carotene equivalent from a standard curve of β-carotene.

Puncture strength

Mango peel puncture strength in g was calculated using a texture analyzer (TA-XTPlus, Make: Stable Micro Systems, UK), the maximum force used to break up the peel. Each fruit peels three times at an equal distance of about 6.00 mm on the equatorial region with a 50 kg load cell and all tests were carried out with a 2 mm stainless steel probe was set to a pre-test speed of 1 mm/s, a test speed of 1 mm/s, a post speed of 10.0 mm/s and a force of 5 g.

Statistical analysis

All experiments were carried out in triplicate. Data were subjected to one-way analysis of variance (ANOVA) for the completely randomized design with storage temperature and storage time as factors (Dean and Voss, 1999). The least significant differences between means were calculated at the ($p<0.05$) level.

RESULTS AND DISCUSSION

The samples were used to determine the net effect of hot water treatment and MAP on the shelf life of Banarasi langra mangoes stored at 10 and 15°C. These treatments' impact on the physiology and quality of fresh mangoes are summarized below:

Fruit weight loss

MAP reduced the weight loss considerably in comparison to the control fruits. Significant ($p<0.05$) weight loss was observed in all samples; however, the maximum weight loss (15.19 g) was observed in untreated mangoes packed in B and stored at 15°C, while the minimum weight loss (10 g) occurred in treated mangoes packed in A and stored at 10°C (Table 1). Both hot water treatment and gas composition were significant ($p<0.05$). Weight loss was positively correlated with O_2 content inside the packaging but

negatively correlated with CO_2 content. Fruit weight loss may have been reduced at low O_2 and high CO_2 concentrations within the package due to decreased transpiration and respiration rates. After 15 days of storage, fruits without MAP lost 8.8 % of their initial fresh weight, exhibiting early signs of skin wrinkling. Fruit firmness decreased as storage time increased and hot water treatment inhibited fruit firmness. Ramayya *et al.* (2012) found weight loss in Alphonso mangoes at 40°C to be slightly lower than at other temperatures (20 and 30°C) stored at 10°C.

Total soluble solids (TSS)

During the storage period, the TSS content of all samples increased significantly ($p<0.05$) (Table 1). At the end of the storage period of 25 days, the maximum increase in TSS was recorded for untreated samples (18.89%) packed in B and stored at 15°C. Compared to the other test samples, the increase in TSS for treated samples packed in A and stored at 10°C was significantly lower ($p<0.05$). The rise in TSS could be attributed to changes in the cell wall structure and the breakdown of complex carbohydrates into simple sugars during storage. This increase and decrease in TSS are directly related to hydrolytic changes in starch. Starch conversion to sugar is an essential indicator of ripening in mango and other climatic fruits (Kudachikar *et al.* 2001). Doreyappy and Huddar (2001) observed a similar pattern of TSS change in mature green Alphanso and different seven hybrid varieties of mango fruit, where TSS content increased from 8.55 to 19.0 Brix during ripening storage at 10-15°C. Similar findings are reported by Karuna *et al.* (2015) in mango cv. Langra and Gupta and Jain (2014) in mango cv. Dashehari in ambient storage conditions.

Table 1: Combined effects of hot water treatment and MAP on pH, % acidity, TSS and weight loss of Banarasi langra mangoes.

	Gas composition							
	A(O_2-7% : CO_2 -50%: N_2 -43%)				B(O_2-15% : CO_2 -5%: N_2-80 %)			
	T 10	UT 10	T15	UT 15	T 10	UT10	T15	UT15
pH								
0	3.47±0.01	3.47±0.01	3.47±0.01	3.47±0.01	3.47±0.01	3.47±0.01	3.47±0.01	3.47±0.01
5	3.49±0.01^{a}	3.52±0.02^{b}	3.53±0.01^{b}	3.62±0.05^{c}	3.5±0.03^{a}	3.52±0.02^{b}	3.51±0.033^{b}	3.54±0.02^{b}
10	3.54±0.01^{a}	3.61±0.01^{b}	3.81±0.017^{ce}	3.99±0.02^{d}	3.51±0.02^{a}	3.56±0.015^{a}	3.79±0.015^{c}	3.85±0.02^{e}
15	3.62±0.025^{a}	3.67±0.01^{b}	3.92±0.015^{c}	4.12±0.015^{d}	3.66±0.02^{b}	3.78±0.01^{e}	3.87±0.035^{c}	3.98±0.015^{f}
20	3.76±0.015^{a}	3.87±0.005^{b}	4.12±0.025^{c}	4.29±0.04^{d}	3.79±0.02^{a}	3.89±0.015^{b}	4.16±0.02^{c}	4.23±0.026^{d}
25	3.88±0.025^{a}	3.95±0.035^{b}	4.35±0.04^{c}	4.61±0.005^{d}	3.99±0.037^{b}	4.11±0.03^{e}	4.34±0.02^{c}	4.46±0.01^{f}
% Acidity								
0	0.076±0.01	0.076±0.01	0.076±0.01	0.076±0.01	0.076±0.01	0.076±0.01	0.076±0.01	0.076±0.01
5	0.072±0.005^{ab}	0.071±0.005^{ab}	0.07±0.001^{ab}	0.069±0.002^{b}	0.075±0.01^{c}	0.074±0.003^{c}	0.073±0.02^{ac}	0.071±0.003^{ab}
10	0.071±0.001^{a}	0.068±0.002^{ab}	0.067±0.001^{b}	0.065±0.005^{c}	0.073±0.015^{a}	0.072±0.001^{a}	0.071±0.002^{a}	0.069±0.002^{ab}
15	0.071±0.002^{a}	0.066±0.001^{b}	0.064±0.01^{bc}	0.062±0.003^{c}	0.071±0.004^{a}	0.069±0.001^{a}	0.065±0.009b^{c}	0.062±0.004^{c}
20	0.069±0.003^{a}	0.063±0.015^{b}	0.061±0.001^{b}	0.057±0.002^{c}	0.069±0.004^{a}	0.067±0.005^{a}	0.058±0.001^{c}	0.057±0.003^{c}
25	0.065±0.002^{a}	0.058±0.005^{b}	0.052±0.005^{c}	0.047±0.002^{d}	0.064±0.006^{a}	0.06±0.009^{b}	0.051±0.004^{c}	0.049±0.005^{d}
TSS								
0	5.17±0.025	5.17±0.025	5.17±0.025	5.17±0.025	5.17±0.025	5.17±0.025	5.17±0.025	5.17±0.025
5	5.74±0.02^{a}	6.65±0.04^{b}	8.11±0.02^{c}	9.79±0.04^{d}	6.44±0.005^{e}	7.06±0.03^{f}	7.79±0.06^{g}	9.79±0.02^{h}
10	6.22±0.05^{a}	7.6±0.02^{b}	9.96±0.01^{c}	11.09±0.009^{d}	7.53±0.04^{b}	8.27±0.004^{e}	10.56±0.001^{f}	11.88±0.001^{g}
15	7.41±0.001^{a}	8.23±0.004^{b}	10.97±0.004^{c}	15.84±0.003^{d}	7.82±0.005^{e}	9.11±0.001^{f}	11.99±0.004^{g}	14.14±0.005^{h}
20	7.85±0.008^{a}	9.79±0.006^{b}	11.89±0.003^{c}	16.8±0.006^{d}	8.07±0.002^{e}	9.55±0.015^{f}	15.08±0.004^{g}	17.38±0.01^{h}
25	11.33±0.006^{a}	13.98±0.002^{b}	14.74±0.001^{c}	18.64±0.005^{d}	13.23±0.002^{e}	14.65±0.003^{c}	17.74±0.001^{f}	18.89±0.002^{g}
Weight loss (g)								
0	0	0	0	0	0	0	0	0
5	2±0.43^{a}	2.3±0.38^{b}	2.5±0.51^{b}	3.5±0.25^{c}	2±0.1^{a}	2±0.82^{a}	2.25±0.23^{b}	2.5±1.2^{b}
10	3.75±0.51^{a}	3.8±0.23^{a}	6±0.33^{b}	8±0.28^{c}	3.5±0.11^{d}	4±0.15^{e}	7.5±0.52^{f}	8.25±0.19^{g}
15	5.25±0.36^{a}	6±1.2^{b}	8.75±0.19^{c}	10±1.4^{d}	5.75±0.33^{e}	6.25±0.4^{f}	8.25±0.26^{g}	9.5±1.4^{h}
20	7.5±0.15^{a}	8.75±0.34^{b}	11±1.6^{c}	12±0.2^{d}	8.25±0.15^{e}	9±0.24^{f}	10.03±0.62^{g}	13.25±0.7^{h}
25	10±0.4^{a}	11±0.5^{b}	13±1.1^{c}	14±0.42^{d}	10.7±0.3^{e}	12±0.5^{f}	13.5±1.3^{g}	15.19±0.28^{h}

Values are given as mean ± S.D. from triplicate determinations. Different superscripts in the same row indicate significant differences ($P<0.05$).

T10- Hot water treated, stored at 10°C, UT10-Untreated, stored at 10°C, T15-Hot water treated, stored at 15°C, UT15- Untreated, stored at 15°.

Acidity

It was found that the product % titratable acidity decreased over a 25-day storage period (Table 1). The reduction in acidity was significantly ($p<0.05$) lower for the treated samples stored under A. The maximum decrease in acidity (0.047%) was recorded for untreated mangoes stored in A at 15°C, followed by untreated samples (0.049%) stored in B at 15°C. A minimum decrease (0.065%) was observed for treated samples stored in A at 10°C, followed by treated samples (0.064%) stored in B at 15°C. This decrease in acidity could be attributed to citric acid degradation during the ripening process. Acidity may be reduced due to their conversion into sugars and subsequent utilization in metabolic processes in the fruit. These findings are consistent with those of Srinivasa *et al.* (2002), who reported that titratable acidity values of Alphonso mango, whether packed in carton or control sample,

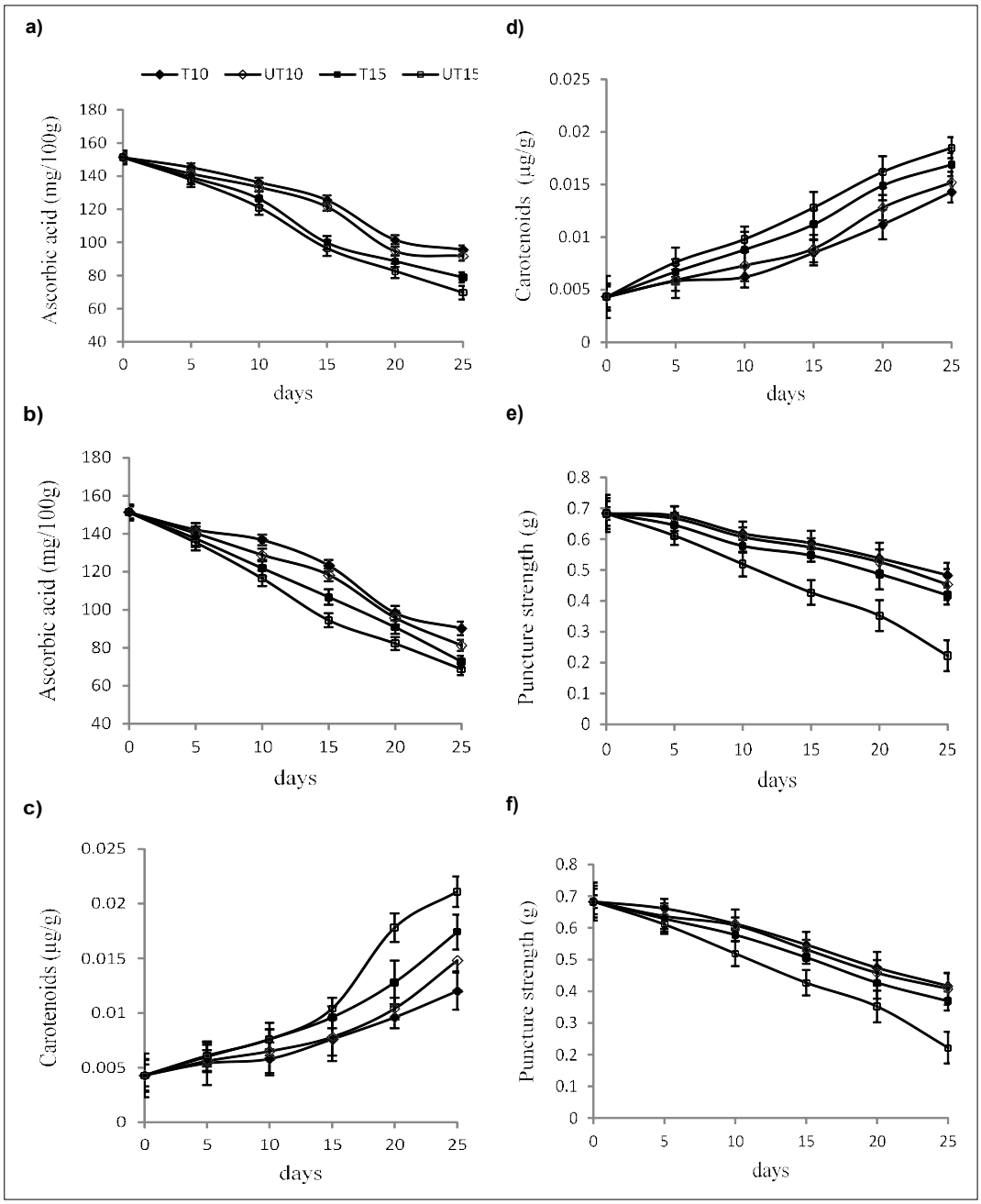

Fig 1: Effect of modified atmospheric packaging on quality of Banarasi langra mangoes. (a) ascorbic acid content under A; (b) under B; (c) carotenoid content under A; (d) under B; (e) puncture strength under A; (f) under B. T10-Hot water treated, stored at 10°C, UT10-Untreated, stored at 10°C, T15-Hot water treated, stored at 15°C, UT15-Untreated, stored at 15°C. Each value calculated represents the mean of 3 replicates ± SD.

decreased to 0.08% from 2.17% after 12 days of storage at ambient temperature 27±1°C and 65% relative humidity. Djioua *et al.* (2009) observed similar changes in hot water-treated 'Keitt' mangoes.

pH

During the storage period, the pH of all mango samples increased. The hot water dip and MAP had a significant ($p<0.05$) effect on the pH, as shown in Table 1. The best results were obtained from treated samples stored in A at 10°C, with a pH (3.88) close to the initial (3.47). The maximum increase in pH, 4.61, was observed in untreated samples packed in A and stored at 15°C. Doreyappy and Huddar's (2001) earlier research findings, in which a significant increase in pH (2.85 to 4.38) and decrease in acidity (2.71 to 0.04 %) were observed during the ripening of different varieties of mango fruit stored at 18-34°C.

Ascorbic acid

Fruits are natural sources of ascorbic acid and its level is known to decrease during processing and ripening. All samples showed a significant ($p<0.05$) reduction in ascorbic acid content from the initial ascorbic acid content of 151.23 mg/100 gm. Mangoes dipped in hot water and stored under A at 10°C showed the slightest average decrease (95.6 mg/ 100 g) but played a vital role ($p<0.05$). The maximum reduction in ascorbic acid content was found for untreated mangoes stored in B at 15°C (68.7 mg/100 gm) (Fig 1a, b). Ascorbic acid content decreases with storage time. Ascorbic acid was oxidized to dehydroascorbic acid during storage by oxidizing enzymes such as ascorbic acid oxidase, peroxidase, catalase and polyphenol oxidase (Mazurek and Pankiewiez, 2012). Djioua *et al.* (2009) and Ramayya *et al.* (2012) found higher ascorbic acid retention in mangoes dipped in hot water maintained at 50°C/30 min and 40°C/40 min, respectively.

Carotenoid content

Fruit color develops evenly due to carotenoids and this pigment is responsible for mangoes' bright yellow color. The carotenoid content of all samples increased over 25 days from an initial value of 0.0043 µg (Fig 1c, d). It was observed that untreated mangoes packed in A and stored at 15°C underwent maximum ripening indicated by the highest carotenoid value of 0.0211µg followed by untreated samples (0.0185 µg) stored in B at 15°C. Treated samples showed a significantly ($p<0.05$) lesser increase in carotenoid value, where the slightest increase of 0.0120 µg was demonstrated by the samples stored in A at 10°C. Mangoes packed under initial A conditions turned to yellowish ripe fruit color faster, followed by other states. The hot water dipping treatment effectively delayed ripening, with mangoes initially dipped in water maintained at (40±2°C) showing the minimal color change. This is consistent with the findings of Ortega-Zaleta *et al.* (2000) and Djioua *et al.* (2009), who found that hot water dipping at high temperatures (40±2°C) is beneficial in maintaining uniform good ripening color of the fruit.

Puncture strength

Shalom *et al.* (1996) reported that one of the main factors contributing to firmness, an essential factor in the fruit selection and retention due to heat treatment, is inhibition of solubilization of the carbonate-soluble pectin fraction. Pectic substances are structural polysaccharides responsible for the firmness of the fruits. Fruit softening occurs when these pectin polymers become less tightly bound in the cell walls during ripening, resulting in a decrease in puncture strength. Fruit firmness differed significantly ($p<0.05$) between treated and untreated samples and between samples stored under different gas compositions. The firmness of treated samples stored in A at 10°C decreases 0.483 g significantly ($p<0.05$). Fig 1e and f showed the untreated samples (0.222 g each) experienced the most significant reduction in firmness when stored in A at 15°C. The decline in puncture strength score during storage could be attributed to the breakdown of insoluble pectic substances to soluble forms *via* a series of physico-chemical changes caused by pectic enzymes such as esterase and polygalacturonidase, which are formed in the tissues during ripening (Weichmann, 1987). The storage temperature also played a significant ($p<0.05$) role in keeping the fruit firm. These findings are consistent with the findings of Opara *et al.* (2000), who found that the firmness of Buoi mango was highly dependent on storage temperature, with an increase in temperature (27°C) accelerating ripening and decreasing firmness. Ramayya *et al.* (2012) found that mangoes dipped in hot water at 40°C for 40 minutes retained firmness better than mangoes dipped at 30 and 20°C.

CONCLUSION

The combined effects of MAP, two different gas compositions A and B, hot water treatment and low-temperature stored treated mangoes were exposed to MAP at 10°C, they improved keeping quality. The degradation of physicochemical and textural properties in hot water-treated mangoes was significantly lower than in untreated mangoes. These findings indicate that a hot water treatment at 40°C for 30 minutes, followed by packing in poly bags with an A concentration and storage at 10°C, is highly effective for achieving good storage quality of Banarasi langra mangoes for 25 days, far superior to the control samples, which showed deterioration after only 12 days. The current findings can be used as a valuable indicator to help extend the shelf-life of mangoes under tropical conditions and open up new avenues for their preservation.

Conflict of interest: None.

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