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Evaluation of physico-chemical, microbial and sensory attributes of minimally processed litchi (*Litchi chinensis* Sonn.) under low temperature storage

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ABSTRACT

Purpose: The main aim of this study was to evaluate the changes in quality of minimally processed litchi fruit during storage at low temperatures (5-7°C). **Research method:** The study attempts to report the efficacies of seven different anti-browning compounds at various concentrations namely methionine (0.1%), cysteine (0.1%), EDTA (0.1%), oxaloacetic acid (1%), ascorbic acid (1%), citric acid (1%), and potassium metabisulfite (0.5%) on quality and shelf-life extension of minimally processed litchi aril. Treated litchi aril kept in trays wrapped with plastic film and stored under refrigerated conditions. Changes in total soluble solids, titratable acidity, ascorbic acid, total phenolics, sensory attributes, colour, weight loss, microbial and activities of polyphenol oxidase and peroxidase enzymes were evaluated. **Findings:** Treatments reduce the weight loss and sensory attributes with higher contents of TSS, titratable acidity, ascorbic acid, total phenolics and suppressed the increase in activities of polyphenol oxidase and peroxidase. Therefore, a postharvest dip of peeled litchi into solutions of chemical preservatives could be suggested to maintain the postharvest quality under refrigeration storage. Treated litchi arils were acceptable (sensory score >7) up to 8 days as compared to 3 days for the control samples during refrigerated storage. **Research limitations:** No limitations were found. **Originality/Value:** Further, 1% ascorbic acid and 1% citric acid were recorded to be the best to preserve the quality of minimally processed 'Mujaffarpur' litchi during refrigeration storage.

INTRODUCTION

Litchi (*Litchi chinensis* Sonn.) is a fruit of high commerce often preferred by the consumers for its sweet acidic taste, excellent aroma, attractive bright red peel colour and high nutritive value (Mphahlele et al., 2020; Phanumong et al., 2016). Though litchi fruit is relished for its nutritive value and claims high price when fresh, it is highly prone to pericarp browning and turns brown within 2–3 days after harvest (Jiang et al., 2012). This results in a short shelf life that narrows down the marketability of the fruit causing huge economic loss to the farmers. Enzymatic oxidation of ascorbic acid and action of polyphenol oxidase and peroxidase enzymes are the major culprits of litchi peel browning (Yun et al., 2020). However, the internal arils remain in good condition, in contrast to the dark brown colour pericarp. Thus, the deteriorated external appearance of the fruit masks the good internal quality of the pulp. This underpins the need for techniques to improve the acceptability of the fruit and prevent loss to the farmers.

In recent years, the demand for minimally processed litchi fruits by the consumers and restaurants has augmented because of the convenience and nutritive quality thus, creating new marketing opportunities (Sarkar & Sumi, 2023). Edible arils of unmarketable brown fruits can be stored for long time by merely peeling and stabilizing the fruit to retain fresh-like characteristics and good postharvest quality (Mphahlele et al., 2020). However, the absence of protective pericarp limits the shelf life of the minimally processed litchi fruit and requires additional treatment to preserve the quality of edible aril to allow its marketing for a sufficient period of time (Phanumong et al., 2015). Moreover, litchi aril is also very prone to dehydration during storage (Jiang & Fu, 2000). Therefore, postharvest technique for preservation of peeled litchi fruits is the need of the hour to maintain good quality of fruit during the entire supply chain till it reaches the consumer.

Hence, the use of GRAS and eco-friendly chemicals with practical applicability is required to control the problem. Organic acids are such GRAS compounds reported to maintain quality and enhance the shelf life of fresh-cut produce (Kumar et al., 2018b; Oms-Oliu et al., 2010; Gorny et al., 2002). Organic acids are also reported as antimicrobial and antioxidant agents that control the enzymatic activity and thereby inhibit the browning reactions (Ventura-Aguilar et al., 2017; Azevedo et al., 2018).

Previously some researchers have worked on minimal processing of litchi fruit to improve the shelf life and maintaining the postharvest quality of arils (Mphahlele et al., 2020; Dong et al., 2004; Bolanos et al., 2010; Kaushik et al., 2014; Phanumong et al., 2015, 2017; Phanumong et al., 2016). However, a comparative analysis of aforesaid chemicals with different concentrations on peeled litchi cv. 'Mujaffarpur' during refrigerated storage is reported for the very first time. Therefore, the objective of this study was to evaluate the effects of chemical preservatives on postharvest quality maintenance and shelf life extension of peeled litchi cv. 'Mujaffarpur'.

MATERIALS AND METHODS

Plant material and sample processing

Litchi (*Litchi chinensis* Sonn.) cv. 'Muzaffarpur' was harvested when fully red, with TSS ≥ 16 from College of Horticulture and Forestry (CHF) farm. Later, the fruits were carefully transported in containers without any damage to the Department of Post Harvest Management laboratory located at CHF, CAU (I), Pasighat and Arunachal Pradesh, India for subsequent processing. Split and cracked fruits were manually separated and uniform sized fruit free from disease were selected.

Selected whole litchi fruits were sanitized in 200 ppm sodium hypochlorite solution for 2 min. After draining, the litchi fruits were manually peeled carefully with a sharp stainless steel knife. Arils obtained were then dipped into distilled water (control), methionine (0.1%), cysteine (0.1%), EDTA (0.1%), oxalic acid (OA) (1%), ascorbic acid (AA) (1%), citric acid (CA) (1%) and potassium metabisulfite (KMS) (0.5%) for 5 min. On the basis of preliminary trials, the concentrations of these individual chemicals were selected for final study. Approximately 12 pieces of arils (~ 150 g) were packed in a tray, shrink wrapped and immediately stored under refrigeration (5 °C) condition for 8 days. After processing of litchi fruits the baseline measurements (0 day) were conducted prior to packaging and storage. During storage period, different quality attributes were analysed including browning metabolism (phenolic content, polyphenol oxidase, peroxidase activity) and other quality factors namely mass loss, colour index, soluble solids content, titratable acidity, ascorbic acid at two days' interval.

Analysis of quality attributes

Weight loss

Weight loss of each package was taken before storage and at each sampling day using an electronic balance (Wensar Weighing Scales Limited, Chennai, India). The loss in weight was expressed in percentage (%) of the initial weight and calculated as follows (1) (Kumar et al., 2017):

$$WL = \frac{Wi - Wf}{Wi} \times 100 \qquad (1)$$

Where, WL is the weight loss (%), Wi is the initial weight (g) and Wf is the final weight (g) at the time of sampling during storage.

Colour attributes

Colour of the arils was measured by using a colourmeter (CS 3260, Analytical Technologies Ltd., Gujarat, India) in CIELAB (L*, a*, b*) coordinates where L* denotes the lightness, a*: red/green and b*: yellow/blue. The whiteness index (WI), as determined by the following equation (2), strongly correlates with consumer preferences, as a higher whiteness index indicates a fresher appearance of the product.

$$WI = 100 - [(100 - L*)^2 + (a*^2 + b*^2)]½ \qquad (2)$$

Browning index (BI), an important attribute in processed foods indicating extent of browning was calculated using the following equation (3).

$$BI = [100(x - 0.31)]/0.172 \qquad (3)$$

Where: $x = (a* + 1.75\,L*)\,/\,(5.646\,L* + a* - 3.012\,b*)$

From the L*, a* and b* values, total colour change (ΔE*) was calculated. ΔE* is an attribute that quantifies the overall colour difference of samples. It was calculated using the following equation (4):

$$\Delta E = 100 - [(100 - L*)^2 + (a*^2 + b*^2)]½ \qquad (4)$$

Soluble solids content, titratable acidity and pH

Soluble solids content (ºBrix) of arils was determined using digital refractometer (Milwaukee Digital Refractometer (MA 871), Milwaukee Instruments, Inc., United States). Titratable acidity (%) was measured by titration with 0.1 N NaOH (Nayak et al., 2019). pH value was estimated by extracting the juice from the litchi using a pH meter (EUTECH INSTRUMENTS).

Determination of ascorbic acid and phenolics content

Ascorbic acid was determined by titrating sample aliquot with 2,6-dichlorophenol indophenol dye and expressed in mg of ascorbic acid per 100 g (Ranganna, 2007). The total phenolic content was determined according to Folin-Ciocalteu assay (Kumar et al., 2017). Wherein methanolic extract of the pulp was mixed with double distilled water, Folin–Ciocalteu reagent and sodium carbonate and the absorbance of colour developed was recorded at 760 nm (Double Beam Spectrophotometer, Systronics 2206). The values obtained were expressed as mg GAE per 100 g of fresh weight.

Extraction and assay of polyphenol oxidase and peroxidase activity

The polyphenol oxidase (PPO) activity was measured as previously described by Kumar et al. (2018a). To determine the polyphenol oxidase activity, 2 g of sample was homogenized in 10 mL of 0.2 M sodium phosphate buffer (pH 6.8) followed by centrifugation at 10,000 rpm for 10 min. at 4 ºC. Aliquots were recovered as enzyme extracts for estimation of polyphenol oxidase activity. The increase in absorbance at 410 nm was recorded for 10 min. with the help of a spectrophotometer (Double Beam Spectrophotometer, Systronics 2206). Enzyme activity was explained as the change of 0.001 in absorbance at 410 nm and represented as min^{-1} g^{-1}.

Peroxidase (POD) activity was determined as per Kumar et al. (2018a). Two grams of sample was ground in 10 mL sodium phosphate buffer (0.1 M), containing 1% polyvinylpyrrolidone (PVP). It was then centrifuged at 10,000 rpm for 10 min. at 4 ºC. The assay mixture consisted of 0.1 M sodium phosphate buffer (pH 7.0), 0.042 % hydrogen peroxide (H_2O_2), 0.07 M guaiacol and 100 µl of enzyme extract in a final volume of 3 mL. The increase in absorbance at 436 nm was noted for 10 min. Enzyme (POD) activity was described as a change of 0.001 in absorbance at 436 nm (Double Beam Spectrophotometer, Systronics 2206) and expressed as min^{-1} g^{-1}. One unit of enzyme activity was defined as the amount of enzyme that caused a change of 0.001 in absorbance per minute.

Subjective Evaluation

The subjective assessment of peeled litchi arils after 8 days of storage was conducted using a 9-point hedonic scale, where a score of 1 represented poor quality, and a score of 9 denoted excellent qualities. A group of 30 panelists, comprising 15 males and 15 females including staff and students participated in the sensory analysis. An orientation program was organized to familiarize the panelists with the testing procedure, the attributes under examination, and the completion of the evaluation form. The samples were assigned three-digit codes and presented to the panelists in a randomized order at around 25°C to minimize any potential positional bias. Additionally, water was provided to the panelists for rinsing their mouths between sample tastings. Panelists were asked to rate their degree of liking for appearance, color, firmness, flavor, and overall acceptability using the 9-point hedonic scale, where a rating of 1 indicated strong dislike, and a rating of 9 indicated strong liking. The mean scores for each parameter were calculated.

Microbial analyses

The evolution of the microbial changes of fresh-cut litchi throughout storage was evaluated by the total aerobic plate counts. 10 g of litchi aril were removed aseptically from each tray and transferred into sterile plastic bags. Litchi samples were diluted with 90 ml of sterile normal saline and homogenized for 1 min. Dilutions were made and then spread plated onto plate count agar medium. Plates were incubated at 30±2 ºC for 48 h. Total aerobic plate counts were counted and the results expressed as log CFU/g (Cappuccino & Sherman 2008).

Statistical analysis

The data collected during the 8-day storage of litchi arils underwent statistical analysis using SAS 9.3 data analysis software. Analysis of Variance (ANOVA) was conducted employing a Completely Randomized Design (CRD) with three replications. The significance level was defined by Tukey's HSD for all tests. Statistical significance level was indicated at $P < 0.05$.

RESULTS AND DISCUSSION

Litchi fruits cv. 'Mujaffarpur' used for the study were found to have an average weight of 22 g and the edible portion accounted for approximately 55% of the total fruit weight. The soluble solids content (°B), pH, titratable acidity (%), ascorbic acid (mg 100 g^{-1}) and total phenols (mg 100 g^{-1}) were 17.4, 5.06, 0.50, 23.89 and 100, respectively. The L* (brightness index) value of aril was 49.55 at the start of the experiment.

Physical changes

Weight loss (WL)

Weight loss (WL) is mainly attributed to moisture loss from a respiring commodity. The weight of treated minimally processed litchi was measured to analyse the efficiency of the browning inhibitors used in the study to act as inhibitors of water loss over the experimental duration. As storage time elapsed, weight of peeled litchi arils decreased gradually (Fig. 1A). All the treatments demonstrated a good ability for minimizing water loss from the fruits when compared with the control litchi fruits. Further, ascorbic acid (1%), citric acid (1%) and methionine (0.1%) demonstrated a better performance for moisture loss inhibition. The findings were in agreement with Phanumong et al. (2015) and Shah and Nath (2008) who subjected the minimally processed litchi fruits with calcium salts and cysteine, ascorbic acid and 4-hexyl resorcinol and stored under low temperature.

Browning index (BI), whiteness index (WI) and total colour (ΔE) changes

Influence of browning inhibitors used in this study on colour attributes (BI, WI and ΔE*) are presented in Figure 1B, and Figure 2A & B. As evident, treatments had a significant effect on the colour changes of peeled litchi arils during storage. Browning of aril is the main issue in peeled litchi fruits. Browning is visible in minimally processed fruits due to tissue damage by cutting operations or exposure to air which results in a loss of natural colour (Chiumarelli & Hubinger, 2012; Oms-Oliu et al., 2010). The browning index (BI) which combines the colour parameters of CIE Lab is an indicator of the degree of brown colour (Olivas et al., 2007). Changes in BI of peeled litchi fruits during refrigerated storage are portrayed in Figure 1B. As shown, control fruits exhibited higher browning index. Treatment of peeled fruits with ascorbic acid (1%), cysteine (0.1%) and methionine (0.1%) curbed the browning till the last day of storage. The effectiveness of these chemicals in retarding the browning process are consistent with the results of Kumar et al. (2018a, b) in minimally processed apple and

Phanumong et al. (2015) in litchi stored under low temperature. A progressive increase in the browning with storage, as observed in our study has also been reported by these authors.

Whiteness index is closely associated with customer choices (Pathare et al., 2013) with a white appearance depicting better freshness of the commodity. WI of the peeled litchi fruit was significantly affected by treatments during storage (Fig. 2A). During 8 days of storage, whiteness index of the minimally processed fruit was higher in arils treated with ascorbic acid (1%) and cysteine (0.1%) and methionine (0.1%) compared to other samples. There was a significant decline (from 48.58 to 36.30) in WI for control fruits. The potential mechanism behind this effect lies in the ability of methionine, cysteine, and ascorbic acid to act as reducing agents, interacting with the active sites of PPO enzymes and consequently inhibiting their activity. This impediment of the enzymatic browning process helps in preserving the whiteness index of the minimally processed litchi (Silveira Alexandre et al., 2022).

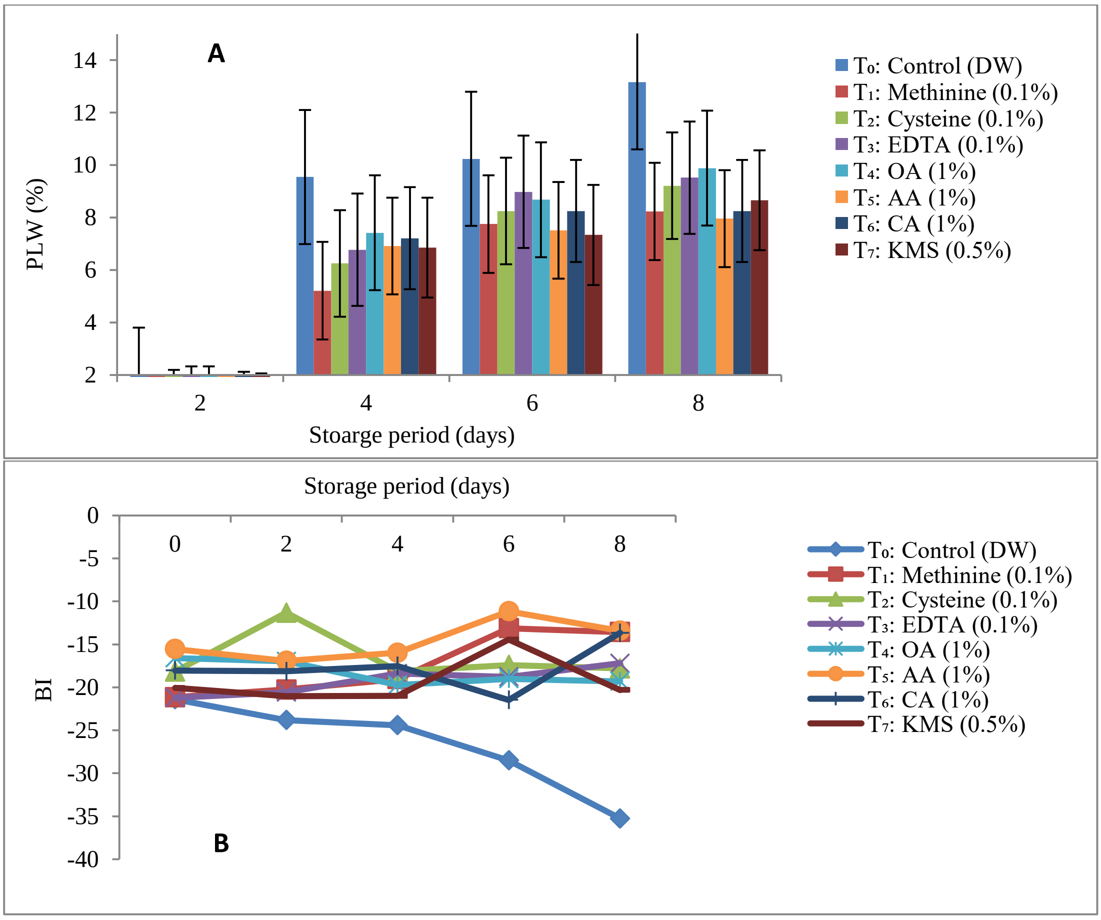

Fig. 1. Changes in physiological loss in weight (PLW) (A) and browning index (BI) (B) of peeled litchi arils given various dipping treatments. Values represent means ± S.E. of 3 replicates.

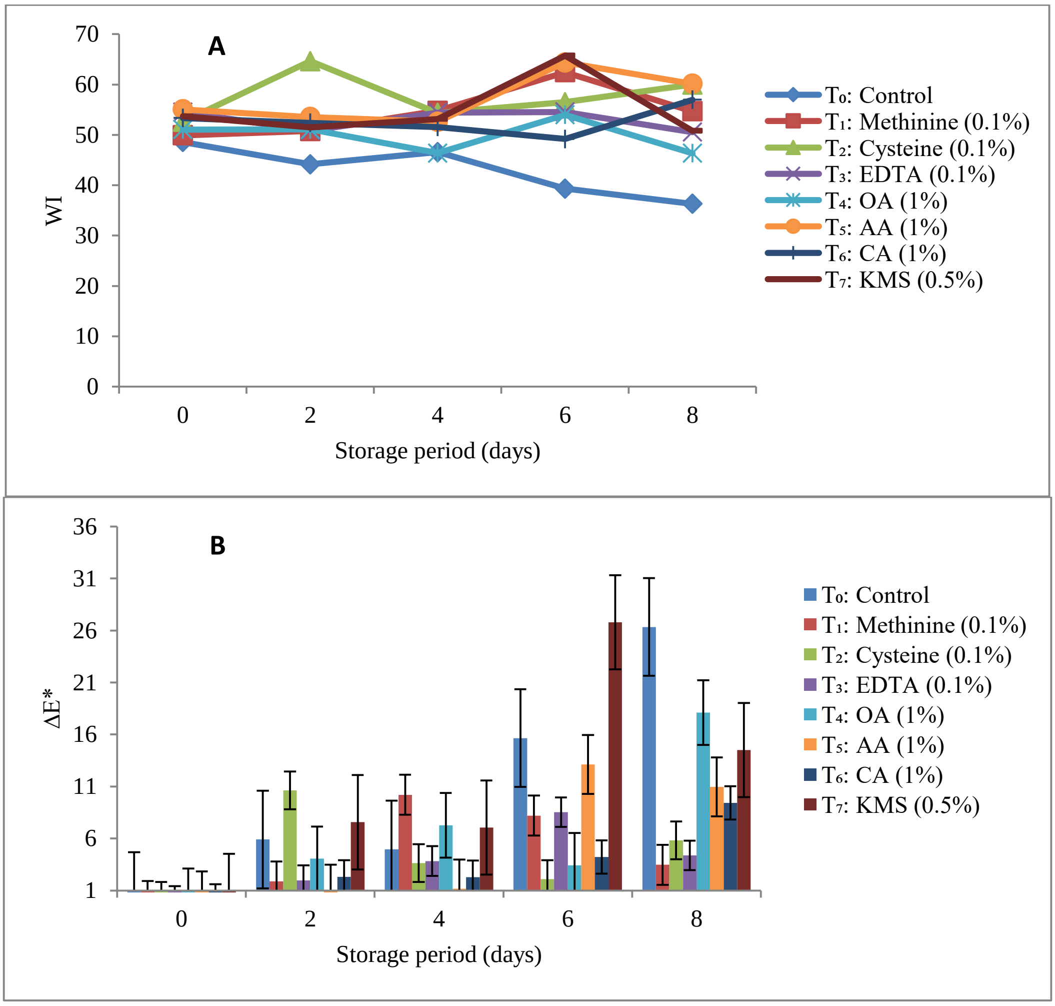

Fig. 2. Changes in whiteness index (WI) (A) and total colour (ΔE*) (B) of peeled litchi arils given various dipping treatments. Values represent means ± S.E. of 3 replicates.

Total colour change (ΔE) of minimally processed litchi fruit was significantly affected by treatments (Fig. 2B). However, samples from untreated lot showed higher colour change (26.34) after 8 days compared to the treated ones. Citric acid treatment of peeled arils resulted in the least ΔE* values (~3.65) in comparison to other browning inhibitors on day 8. For the peeled arils treated with methionine, the increase in ΔE* values was significant till 4^{th} day as shown in Figure 2B, after which rate of increase of ΔE* reduced. Increase in ΔE* is a result of physicochemical and enzymatic changes in fruit (Lamikanra & Watson, 2001) though at a slower rate due to chilled temperature storage. The increase in browning of arils can be attributed to the activity of enzymes such as polyphenol oxidase and peroxidise as observed in our experiments. Samples treated with ascorbic acid, citric acid and cysteine also showed comparatively lesser change in ΔE* over the storage period and thus good colour stability.

Chemical changes

Soluble solids content and titratable acidity

Soluble solids content of litchi arils decreased significantly during storage from an initial value of 17.4-17.8 to 9.1-13.1 ºBrix (Table 1). Arils treated with ascorbic acid (1%), citric acid (1%), methionine (0.1%) and cysteine (0.1%) maintained higher total soluble solids content throughout the storage period. The decrease in the total soluble solids and titratable acidity during storage occurs as a result of utilization of sugars and organic acids in various metabolic activities (Tassou & Boziaris, 2002). These results are in accordance with Shah and Nath (2008), who reported that the total soluble solids significantly reduced during storage of 20 days at 4 °C in minimally processed litchi fruits subjected to osmo-vacuum, moderate vacuum packing and browning inhibitors. Similar observations were also made by Dong et al. (2004), Kumar et al. (2018a) and Soliva-Fortuny et al. (2004) yielding a significant reduction in soluble solids content in treated minimally processed fruit under low temperature storage.

Titratable acidity (TA) was significantly influenced by the different chemicals applied on the peeled litchi fruits (Table 1). At day 0, the titratable acidity level was 0.52% across all treatments and declined gradually with storage period irrespective of treatment. A significant decline in titratable acidity (~57 %) was observed in control samples after 8 days of storage. Treated litchi fruits exhibited a non-significant change in titratable acidity during storage. Fruit treated with ascorbic acid (1%) and citric acid (1%) had slightly higher titratable acidity than other treatments after 8 days of storage. At the termination of experiment, the titratable acidity was 0.38, 0.37 and 0.35 % for arils subjected to ascorbic acid (1%), citric acid (1%) and KMS (0.5%), respectively. However, there were no significant differences between treatments. Similarly, Dong et al. (2004) observed a significant reduction in titratable acidity in peeled litchi treated with chitosan coating.

Ascorbic acid (AA) content

Ascorbic acid is one of the important nutrients in horticultural produce with biological significance (Paciolla et al., 2019). In all the treated arils, AA content was higher than that of control during the 8 days of storage (Table 2). This suggests that all the treatments possessed the ability to maintain ascorbic acid content in litchi arils. Ascorbic acid (1%), methionine (0.1%) and cysteine (0.1%) treatments performed best among all. This may be attributed to prevention of the enzymatic oxidation of AA. Ascorbic acid content initially was 23.86–24.35 mg 100^{-1} g (Table 2). Higher initial AA content in litchi fruits treated with ascorbic acid (1%) was due to the inhibitions of AA into the fruits. However, in general, ascorbic acid content reduced significantly across all the treatments at end of 8 days of cold storage. Similar decline in AA content during low temperature storage has been reported by Kaushik et al. (2014) in minimally processed litchi. The loss of AA has been attributed to its high reactivity to oxygen and its degradation has been associated with browning process (Gimnez et al., 2003).

Table 1. Changes in total soluble solids and titratable acidity of peeled litchi arils given various dipping treatments and stored under refrigeration condition.

Treatment	TSS (°B)					Titratable acidity (%)				
	Storage period (days)					Storage period (days)				
	0	2	4	6	8	0	2	4	6	8
Control (DW)	17.4^{a}	15.3^{ab}	13.3^{ab}	11.2^{ab}	9.1^{b}	0.501^{ab}	0.389^{ab}	0.326^{ab}	0.289^{ab}	0.211^{b}
Methinine (0.1%)	17.8^{a}	16.3^{a}	14.1^{ab}	12.8^{ab}	11.4^{ab}	0.523^{ab}	0.456^{a}	0.412^{a}	0.385^{ab}	0.336^{ab}
Cysteine (0.1%)	17.7^{a}	16.1^{ab}	13.9^{ab}	12.5^{ab}	11.3^{ab}	0.523^{a}	0.451^{a}	0.405^{ab}	0.336^{ab}	0.312^{ab}
EDTA (0.1%)	17.6^{a}	16.2^{ab}	14.0^{ab}	13.2^{ab}	12.2^{ab}	0.512^{a}	0.506^{a}	0.412^{ab}	0.342^{ab}	0.321^{ab}
OA (1%)	17.4^{a}	16.3^{a}	14.4^{ab}	12.7^{ab}	12.2^{ab}	0.532^{a}	0.500^{a}	0.514^{a}	0.386^{a}	0.337^{ab}
AA (1%)	17.7^{a}	16.5^{a}	14.4^{ab}	13.6^{ab}	13.1^{ab}	0.534^{a}	0.502^{a}	0.465^{a}	0.398^{a}	0.379^{ab}
CA (1%)	17.5^{a}	16.4^{a}	14.1^{ab}	13.2^{ab}	13.0^{ab}	0.524^{a}	0.489^{a}	0.456^{a}	0.375^{a}	0.366^{ab}
KMS (0.5%)	17.4^{ab}	16.1^{a}	13.8^{ab}	13.1^{ab}	12.9^{ab}	0.514^{a}	0.478^{a}	0.435^{a}	0.375^{ab}	0.354^{ab}

*Means with same superscript are not significantly different.

Table 2. Change in ascorbic acid content of peeled litchi arils given various dipping treatments and stored under refrigeration condition.

Treatment	Ascorbic acid (mg/100 g)				
	Storage period (days)				
	0	2	4	6	8
Control (DW)	23.89[a]	21.56[a]	18.65[a]	15.32[ab]	12.68[b]
Methinine (0.1%)	24.15[a]	23.63[a]	22.14[a]	20.24[a]	19.21[a]
Cysteine (0.1%)	24.20[a]	23.55[a]	21.99[a]	19.85[a]	18.98[ab]
EDTA (0.1%)	23.87[a]	22.65[a]	21.56[a]	19.21[a]	18.23[ab]
OA (1%)	23.86[a]	22.12[a]	21.12[a]	19.86[a]	17.82[ab]
AA (1%)	24.32[a]	23.75[a]	22.56[a]	20.28[a]	20.12[a]
CA (1%)	24.25[a]	23.14[a]	21.85[a]	20.21[a]	19.78[a]
KMS (0.5%)	24.35[a]	22.62[a]	21.45[a]	19.58[a]	17.89[ab]

*Means with same superscript are not significantly different.

Total phenolic content

Mechanical damage and oxidative damage due to the minimal processing triggers physical stresses owing to alteration in phenolic metabolism in minimally processed tissues. Figure 3A represents the variations in total phenolic content of control and treated peeled litchi stored under refrigerated conditions. The initial phenolic content in litchi arils was 100-100.91 mg GAE 100 g^{-1} which reduced as storage progressed. However, the declining trend was not similar in all the litchi samples. At the termination of experiment, total phenolic content corresponding to control, methionine treated and ascorbic acid treated samples were 61.36, 93.18 and 90.91 mg GAE 100^{-1} g FW, respectively. It is evident that methionine and ascorbic acid treatments were more effective in retaining phenolic compounds. The minimal changes in total phenolics recorded in treated samples may have been associated with the low polyphenol oxidase activity. Aquino-Bolanos and Mercado-Silva (2004) and Bolanos et al. (2010) also reported decline in phenolics with the progress of time in minimally processed litchi and cut jicama, respectively. Higher phenolic content in ascorbic acid treated samples may be because of the ability of ascorbic acid to reduce quinones to phenolic compounds that led to inhibition of browning in tissue. Nonetheless, the extent of potential for browning inhibition could be affected by the amount and nature of phenolic compounds (Altisent et al., 2014).

Polyphenol oxidase (PPO) and peroxidase (POD) activity

Minimally processed products deteriorate faster than intact produce because of browning of the cut surface. Enzymatic browning degrades the slices visual appeal, marketability, and nutritional and sensory value (Farooq et al., 2023; Kumar et al., 2018a). As soon as the fruits are subjected to minimal processing operations, deteriorative changes are initiated and decompartmentalization of the cell constituents is initiated. Oxidative reactions between polyphenolic substrates with enzymes such as polyphenol oxidase (PPO) and peroxidase (POD) take place causing browning. Effect of different treatments on polyphenol oxidase activity of peeled litchi is shown in Figure 3B. Polyphenol oxidase (PPO) activity in untreated samples was 106 U g^{-1} min on day 0, which increased as storage time progressed till day 4 (142 U g^{-1} min) then sharply showing a decline. The maximum increase in PPO activity throughout the storage period was observed in control fruit as compared to treated ones. The highest mean value of 119 U g^{-1} min was found in control peeled fruit and lowest 107, 108 and 110 U g^{-1} for ascorbic acid (1%), methionine (0.1%) and CA (1%) and KMS (0.5%) treated samples, respectively during 8 days of storage. The results indicate the reduction of polyphenol oxidase activity by the treatments applied. However, the extent of reduction varied with the chemical used. Similarly, Dong et al. (2004) also recorded an increase in polyphenol oxidase activity in minimally processed litchi fruit stored under low temperature.

Organic acids including ascorbic acid and citric acid have been reported to exhibit an inhibitory effect on polyphenol oxidase and its anti-browning activity in minimally processed produce (Ahvenaien, 1996; Altunkaya et al., 2008).

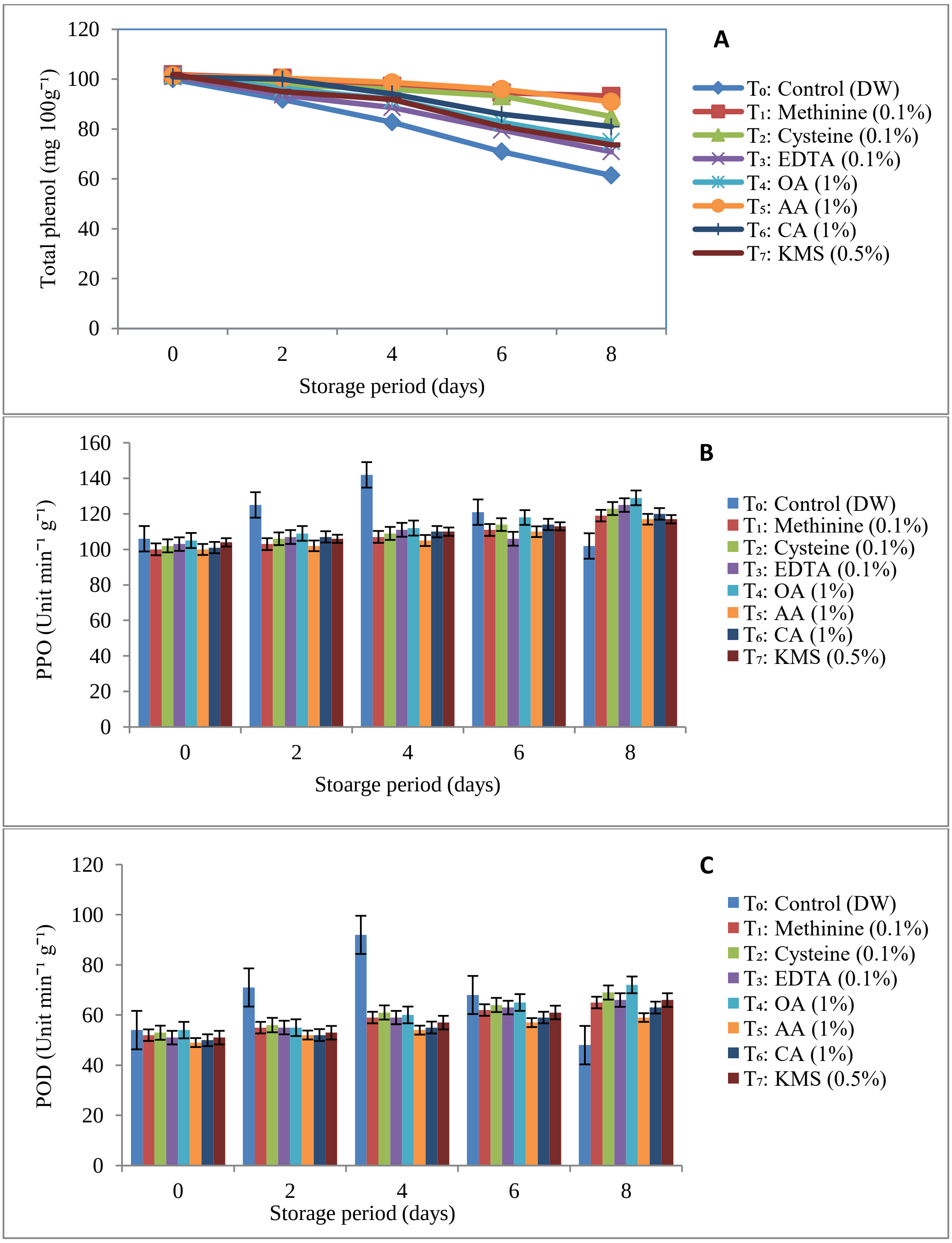

Fig. 3. Changes in total phenolics (A), polyphenol oxidase (PPO) (B) and peroxidase (C) activity of peeled litchi arils subjected to various chemical dips. Vertical bars represent the standard error of the means.

Peroxidase activity is involved in the defence system against oxidative stress and damage repair mechanisms in fresh-cuts leading to colour changes on the exposed surface (Aquino-Bolaños & Mercado-Silva, 2004). Peroxidase activity of control fruit increased rapidly up to day 4 but showed a sudden decline from day 6 of storage. Similar behaviour of elevation in peroxidase activity during the initial storage period and a decline in the latter part of storage of control slices of peach was recorded by Li-Qin et al. (2009). The treated samples showed a gradual increase in peroxidase activity throughout the storage and differed significantly from the control samples (Fig. 3C). The maximum activity of peroxidase enzyme at the end of the storage was observed in control fruit (48 U min^{-1} g^{-1}). The overall analyses of the results suggested that all the chemical treatments were effective in reducing the peroxidase activity. Similar observations of controlling the peroxidase activities by ascorbic acid were noted by Lamikanra and Watson (2001), and Kuwar et al. (2015) in case of minimally processed cantaloupe and papaya, respectively. Both polyphenol oxidase and peroxidase activities are essential factors having influence on the quality of tissue as they affect content of phenolics and the rate and intensity of enzymatic browning.

Sensory quality

Changes in sensory parameters such as appearance, colour, firmness, flavour and overall acceptability of peeled litchi arils as influenced by different treatments were analyzed during storage for 8 days (Fig. 4). Colour scores for arils significantly decreased during the 8-day storage. Litchi fruit treated with ascorbic acid (1%), citric acid (1%), and methionine (0.1%) had significantly higher colour score due to lesser. Firmness scores were also recorded to decline during 8 days of storage. This decline may be attributed to the loss of drip from arils during storage which gave a shrink appearance to litchi fruit and hence loss in turgidity. At termination of the experiment, the flavour scores of arils were found to range from 4.3 to 8.7 which reduced during the storage for all the samples due to loss in sugars. Arils dipped in citric acid (1%), methionine (0.1%) and ascorbic acid (1%) had significantly better flavour during storage due to higher sugar content. Based on the overall acceptability, arils dipped in ascorbic acid (1%), citric acid (1%) and methionine (0.1%) were acceptable up to 8 days. These findings are in agreement with previous studies by Shah and Nath (2008) who treated the peeled litchi arils with cysteine, ascorbic acid and 4-hexyl resorcinol and stored under low temperature (4±2 °C).

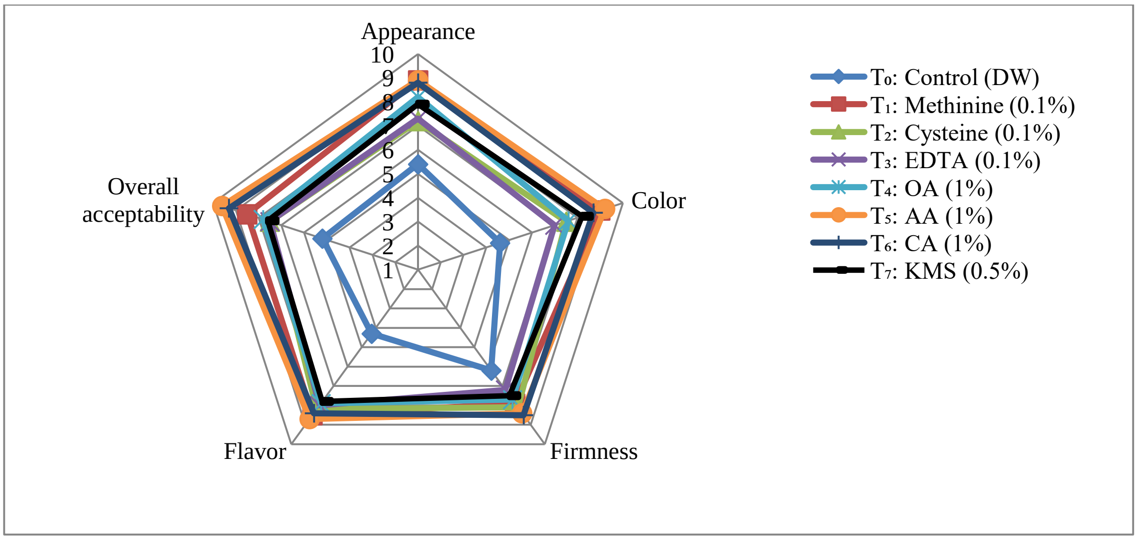

Fig. 4. Subjective quality evaluation of minimally processed litchi stored under refrigeration condition for 8 days.

Microbiological analysis
Microbial growth in all treatments increased as the storage period progressed which was consistent with the results reported by Kumar et al. (2018b). Total microbial counts increased by 5 log CFU/g on untreated litchi arils while microbial loads on treated fruit increased by 3.0-4.0 log CFU/g throughout the storage regardless the applied treatment. Hence, untreated control litchi arils showed markedly higher microbial counts at 8 days of storage than minimally processed litchi subjected to different treatments. Ascorbic acid (1%) treatment was markedly effective in inhibiting the growth of microorganisms in minimally processed litchi at refrigerated conditions (<5 log CFU/g on day 8) and maintained lowest level among all treatments throughout 8 days of the storage. After eight days of storage, for fresh-cut litchi treated by Methinine (0.1%) microbial counts did not exceed 5 log CFU/g while in the control microbial counts were over 5 log CFU/g.

CONCLUSION

Chemical treatments were found to be effective in stabilizing the colour, biochemical and sensorial changes in peeled litchi arils stored under refrigerated condition. The shelf life was extended to 8 days by ascorbic acid (1%), citric acid (1%) and methionine (0.1%) treatments as compared to 3 days for untreated ones. Considering health issues and consumer acceptance, organic acids are perceived as natural additives and can be used at industrial level. The use of organic acids is a feasible and convenient method of preservation for fresh-cut produce. On the basis of overall sensory quality, enzyme activities and effect on nutritional constituents of arils, 1% ascorbic acid and 1% citric acid were recorded to be the best to preserve the quality during refrigeration storage.

Conflict of interest
The authors have no conflict of interest to report.

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