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Research Article

INFLUENCE OF PRETREATMENTS ON POST-HARVEST QUALITY CHARACTERISTICS AND SHELF LIFE EXTENSION OF GREEN TAMARIND FRUITS STORED UNDER DIFFERENT CONDITIONS

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Abstract- In the present study, an attempt was made to prolong the shelf life and to preserve post-harvest quality of fresh tamarind fruits pretreated with fruit hardening chemical agents and aroma chemical compound stored under different storage (Room temperature and low temperature storage) conditions. Optimally matured (TSS 9-10°Brix) fresh and green tamarind fruits were first water washed, sorted to remove mechanically damaged and deformed ones and graded for uniform size, colour, texture and then hydro-cooled for 10 minutes, followed by the post-harvest dip treatments [T_0–Control (Untreated), T_1-0.25% Calcium chloride, T_2-0.5% Calcium chloride and T_3–500ppm Phenyl acetaldehyde] for 10 minutes. Both control and treated fruits were surface dried using mechanical driers, then packed into plastic trays with proper cushioning material and stored at RT(29±2°C, 65-70%) and low temperature (LT) conditions (4±1°C,90-95% RH). These stored fruits were periodically analyzed for changes in various physiological and physico-chemical quality attributes. The results on LT and RT storage studies indicated that tamarind responded very well to fruit hardening salt, calcium chloride at 0.50% in terms of retention of fruit firmness, fruit color and total phenolic, apart from reduction in physiological loss in weight, effective shelf life of tamarind fruits in fresh form up to 28 days at LT and 16 days at RT storage conditions as against 16 days and 8 days respectively in untreated controls when stored under same conditions.

Keywords- Calcium chloride, Green tamarind, Phenyl acetaldehyde, Postharvest quality attributes, Shelf-life

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Introduction

Tamarind *(Tamarindus indica* L.) is a dicotyledonous perennial herb belonging to *Leguminosae* or *Fabaceae* family. Its local names based on cultivating countries include Indian date (in English), *asam jawa fruit* (Malay), *siyambala* (Sinhala), *sampalog* (Philippines) and *puli* in Tamil [1, 2]. It's originated from tropical Africa and has been naturalized in other parts of North and South America, Florida and Brazil. Presently, this cultivated in subtropical countries like China, India, Pakistan, Indochina, Philippines, Java and Spain. The pulp of tamarind fruit contains tartaric acid, which make it acidic in taste. Its composition also contains reducing sugar, pectin, proteins, fibrous and cellulosic materials. The composition differs widely; for example, tartaric acid: 8–18%, reducing sugars 25–45 % (in ripe), pectin 2–3.5% and proteins 2–3%. Tamarind pulp is rich in several phyto-nutrients that provides powerful dietary antioxidants and total phenolic content and therefore, it is used widely for domestic and industrial purposes [3]. It is considered as a food and has applications in traditional herbal medicines to treat diseases like its role in lowering the serum lipids, prevent the cardiovascular diseases [4] and also provide immune regulatory advantages on intestine, lowering the postprandial glucose response as reported by [5]. Reddish-brown color of fruit on ripening initiation, turns to black or black brown with more aromatic and sour as ripening progress [6, 7].

Calcium salts are used preferably in food industries as preservative to prolong the shelf life of stored fruits through pre-harvest treatment [8] and postharvest treatments like beneficial effect of calcium salts on storage stability and quality attributes of fresh as well as processed products of guava, shelf life and keeping quality, extension of sapota and fig fruits [9-11]. Calcium, being a constituent of cell wall having an important function in carbohydrate conversion to sugars [12]. It helps fruit to retain firmness and other visible quality attributes by maintaining the middle lamella cells [13]. It can play an important role in fruits firmness, storability with better quality attributes, because this makes cell wall less accessible to the enzymes that are responsible for fruit softening. This practice of control ripening, as well as decay at the same time [14,15,11]. Among the calcium salts, calcium chloride salt has been widely used as preservative and firming agent in food industries for whole and fresh cut produce. Its effect has been reported by [16] on ripening behaviour, size, shape and shelf life of Totapuri mangoes.

Phenyl acetaldehyde is an important volatile compound produced by plants, which contribute to flavor in fresh produce. These volatile compounds are synthesized from various precursors includes fatty acids, carotenoids and amino acids. The aroma volatile compound 2-phenyl acetaldehyde is derived from amino acid-phenylalanine through decarboxylation reaction and oxidative removal of the amino group. It has pleasant fruity, floral odors [17]. The lipophilic nature of volatile compounds with high vapor pressure enables them to cross the cell membranes freely. It has been reported that Phenyl acetaldehyde having phytotoxic, algicidal and antifungal activities upto the concentration of 400ppm in in-vivo condition as shown by [18]. Thus, it can influence and improve the death efficacy of target microorganism, which can cause deterioration in fresh commodity. The capability of the fruit storage for longer periods without damaging its quality attributes and to supply the fruits according to the required optimum maturity such as green mature, half ripe or full ripe to the consumer market is necessity and depending upon the consumers preferences of as well as to the fruit processing industries. However, required scientific knowledge about the physiological and physico-chemical characteristics of the green matured stage fruit is generally very scanty as almost all the data reported are for the fruits at unique point of maturity - the ripe stage. Therefore, the aim of the present study was to increase the shelf life of green, unripe, fresh form of tamarind using hardening chemical-calcium chloride and volatile aroma compound-Phenyl acetaldehyde and to assess the fruit compositional changes associated with storage under different temperature conditions during the course of storage study.

Materials and Methods

Chemicals

All reagents of analytical grade were procured from SD Fine chemicals Ltd., Mumbai, India and Sigma Aldrich chemicals pvt Ltd., Bengaluru, India. Solvents were obtained from Fisher Scientific India pvt Ltd., The phenolic standards were obtained from Sigma Aldrich chemicals pvt Ltd., Bengaluru, India. Millipore quality of water was obtained from Millipore India pvt Ltd., Bengaluru, India. Fruit hardening chemical reagent calcium chloride and aroma compound Phenyl acetaldehyde were obtained from Sisco Research Laboratories pvt Ltd., India and Merck Ltd., Bengaluru, India.

Selection of Raw materials

Optimally matured green tamarind fruits (9-10^0 Brix) were harvested early in the morning from the fruit orchard, near Mysore, India. Fruits placed in corrugated cardboard boxes were transported immediately to the laboratory and were transferred to the pre-cooling storage system (maintained at 12 ±1^0 C, 90-95 % RH) for 12h to reduce field heat and fruit respiration rate.

Preparation and treatment of green tamarind fruits

Fruits after precooling were sorted and graded for uniform size and firmness and grouped into various fruit lots for post-harvest dip treatments. Aqueous solutions of calcium chloride (0.5 and 1%) and Phenyl acetaldehyde (500ppm) were prepared in potable water. The concentration of Phenyl acetaldehyde was fixed to 500ppm as it has phytotoxic, algicidal and antifungal activities up to 400ppm in-vivo condition as already shown by [18]. Thus, it can influence and improve the death efficacy of target microorganism, which can cause deterioration in fresh commodity. The different levels of calcium chloride were taken with a view to optimize the concentration of calcium chloride salt concentration. 48 kg of green tamarind fruits were divided into four lots of each 12 kg per treatment. Each lot was divided into triplicates for each treatment. Each replication consisted of 4kg fruits. Each lot was dipped in the chemical solution for 10 minutes and surface air dried in a mechanical dryer. Treated fruits along with control were stored at RT (29±2°C, 65-70%) and LT (4±1°C, 90-95% RH) conditions. The stored fruits were periodically analyzed for changes in various physico-chemical quality characteristics in triplicates and the average values for each quality parameters are presented.

Storage studies of fresh green tamarind under various post-harvest treatments

Physicochemical characteristics

Physiological loss in weight (PLW)

PLW was calculated based on initial weight and loss in weight during RT and LT storage studies. The difference between initial and final weight divided by initial weight is PLW and is expressed in terms of percentage (%).

Texture Analysis

Fruit texture was measured in terms of shear test by using the Texture measuring system (LLOYD, Model LR5K) fitted with the Warner blatzler blade of 1.016mm thickness with load cell 1KN) and cross-head speed of 50mm/min. The randomly selected fruits were placed at the base of the Texture measuring system (LLOYD, Model LR5K).The maximum force (N) used was defined as firmness.

Fruit Color (in terms of CIE values-L*, a*, b*)

Fruit Colour measurement was taken out at three portions of each individual fruit using Colour measuring system (SHIMADZU, Model: UV 2100) at wavelength ranging from 400 to 700 nm and expressed in terms of L*, a* & b* values.

Total Soluble Solids (TSS in ^{o}Brix)

The TSS of the homogenate sample was measured using Hand Refractometer (Model: Erma, Tokyo) and is expressed in terms of ^{o}Brix.

Titrable Acidity (%)

Acidity of homogenate sample was estimated as per the method [19] and is expressed as percentage of anhydrous tartaric acid.

Sugars (as total sugars and reducing sugars)

The total sugars and reducing sugars in homogenate samples of tamarind fruit were estimated as per the procedure of Lane and Eynon method [20] and expressed as percent sugar.

Total phenolic content (mg GAE/100g)

It was estimated by using Folin-Ciocalteau assay as per the method [21]. Briefly, 100µl of sample extract was mixed with 2.9ml of distilled water in a tube, followed by addition of 500µl of Folin-Ciocalteau reagent. After 3 min, 2ml of Na_2CO_3 (20%) solution was added in each tube and allowed to stand in dark for 30 min. The absorbance was measured at 765nm by using UV-VIS spectrophotometer (UV-1700 Pharma Spec by SHIMADZU). The total phenolic content in the sample was worked out by using Gallic acid standard calibration curve and expressed as mg of Gallic acid equivalent (GAE)/100g of green tamarind.

Ascorbic acid (mg/100gm)

The titrimetric method with 2, 6-dichloro phenol indophenol reagent was used for vitamin C determination [22] with slight modifications. Briefly, 10g of homogenized fruit pulp was mixed with 100ml of 4% oxalic acid solution. The mixture was homogenized finely and filtered. 5ml of filtrate was diluted to 10ml with 4% oxalic acid solution and titrated with 0.02% of 2, 6-dichlorophenolinodo phenol solution till pink color observed which persist for at least 15 seconds and expressed as mg of ascorbic acid per 100g of green tamarind.

Ascorbic acid

$$(mg/100g) = (0.5\ mg/V1) \times (V2/15ml) \times (100ml/\ Wt.\ of\ Sample) \times 100$$

Where, V1 and V2 are quantity of dye used for standard ascorbic acid and Sample.

PH

10 g of sample was homogenized in 25ml of distilled water and pH was taken using pH meter (EUTECH Instruments-pH Tutor).The experiment was performed in triplicate for each sample taken.

Results and Discussion

Physico-chemical and Physiological changes in pre-treated tamarind fruits during storage under different conditions

PH

The pH was found to be gradually increasing during the storage period of 28 days. There was significant difference ($P<0.05$) in pH changes during period of study among treatments given irrespective of storage temperature as shown in [Table-1 and 2]. The treatment T_2 (calcium chloride 0.5%) showed the lower pH (LT-2.82±0.04 and RT-2.79±0.01) increase during the study at low temperature as well as at room temperature followed by the calcium chloride (T_1-0.25%) and phenyl acetaldehyde (T_3-500ppm) in comparison to control. The low temperature with treatments also showed increase in shelf life of green tamarind by more than 1 week. The lower pH in calcium treated samples with 0.5% might be due to low level of organic acid production in mature but unripe fruits which can be due interference with fruit ripening .The adsorbed calcium chloride might have modified the internal atmosphere of fruit thus lowering the breakdown of organic acid [23]. Phenyl acetaldehyde being having antimicrobial and antifungal activity was able to increase shelf life of tamarind fruit by preventing the fruit deterioration from bacteria and fungi [18].

Titrable acidity

Among the treatments, significant (P<0.05) changes in titrable acidity during storage at different temperature conditions were observed. T_2 showed lower titrable acidity increment (9.98%) after 16 days than T_1 and T_3 at RT storage [Table-2]. At LT, Lower change in titrable acidity (9.74%) was observed for T2 but there was not much difference between treatments given was seen but better results than control for 28 days [Table-1]. Titrable acidity is being related to presence of organic acids mostly tartaric acid, which is synthesized from primary carbohydrate products of photosynthesis. The content of tartaric acid does not decrease during ripening and thus most acidic in nature [24] and also the low titrable acidity in case of treated samples may because of prevention of bacterial or fungal attack and deterioration in fruits which are significant for maintaining quality of fruit [25,26].

Table 1- *Quality parameter of Green tamarind during LT storage (4±2°C,)*

Parameters	Storage Period (Days)	Treatments and Codes			
		T0 Control	T1 Calcium Chloride (0.25%)	T2 Calcium Chloride (0.5%)	T3 Phenyl Acetaldehyde (500ppm)
pH value	0	2.58±0.01^{j}	2.58±0.00^{j}	2.59±0.01^{j}	2.59±0.01^{j}
	8	2.68±0.01^{f}	2.64±0.00^{h}	2.62±0.00^{i}	2.65±0.00^{gh}
	16	2.75±0.01^{d}	2.72±0.01^{e}	2.66±0.01^{fg}	2.71±0.01^{e}
	28	2.98±0.00^{a}	2.86±0.01^{b}	2.82±0.04^{c}	2.83±0.01^{c}
Titrable Acidity (%)	0	6.32 ± 0.01^{g}	6.24 ± 0.05^{g}	6.22 ± 0.02^{g}	6.05 ± 0.04^{h}
	8	7.20 ± 0.08^{e}	6.94 ± 0.02^{f}	6.82 ± 0.06^{f}	7.10 ± 0.08^{e}
	16	7.67 ± 0.01^{c}	7.60 ± 0.08^{cd}	7.50 ± 0.00^{d}	7.54 ± 0.02^{e}
	28	10.19 ± 0.06^{a}	9.84 ± 0.18^{b}	9.74 ± 0.04^{b}	9.78 ± 0.14^{b}
T.S.S (°Bx)	0	9.76±0.06^{l}	9.66±0.12^{l}	9.73±0.06^{l}	9.7±0.17^{l}
	8	10.40±0.00^{h}	10.20±0.00^{jk}	10.13±0.06^{k}	10.26±0.06^{i}
	16	11.20±0.00^{e}	10.93±0.06^{f}	10.63±0.06^{g}	10.89±0.09^{f}
	28	14.12±0.03^{a}	12.52±0.04^{c}	11.63±0.06^{d}	12.76±0.06^{b}
Total phenolics (mgGAE/100gm)	0	52.23±0.94^{i}	53.42±0.37^{hi}	52.76±0.54^{hi}	53.26±0.23^{hi}
	8	56.45±0.18^{g}	54.29±0.86^{ghi}	53.15±0.06^{hi}	54.97±0.52^{gh}
	16	74.14±1.04^{d}	69.82±0.48^{e}	65.82±1.08^{f}	68.94±1.24^{e}
	28	123.20±1.30^{a}	112.15±0.72^{b}	105.76±0.84^{c}	113.33±0.20^{b}
Reducing Sugar (%)	0	0.64±0.20^{g}	0.64±0.01^{g}	0.66±0.02^{g}	0.65±0.01^{g}
	8	0.71±0.01^{ef}	0.70±0.01^{ef}	0.68±0.01^{f}	0.69±0.02^{f}
	16	0.82±0.01^{d}	0.74±0.00^{e}	0.72±0.01^{ef}	0.74±0.00^{e}
	28	1.19±0.08^{a}	0.95±0.02^{b}	0.89±0.01^{c}	0.99±0.01^{b}
Total Sugar (%)	0	8.50±0.06^{kl}	8.55±0.02^{k}	8.52±0.06^{kl}	8.52±0.12^{kl}
	8	9.58±0.21^{i}	9.24±0.02^{j}	9.17±0.09^{j}	9.27±0.06^{j}
	16	11.20±0.00^{e}	10.59±0.035^{g}	10.39±0.04^{h}	10.97±0.03^{f}
	28	18.46±0.12^{a}	16.63±0.12^{c}	16.15±0.09^{d}	17.96±0.12^{b}
PLW (%)	8	2.44±0.03^{h}	1.09±0.01^{l}	1.94±0.01^{j}	2.19±0.01^{i}
	16	3.26±0.04^{c}	1.86±0.04^{k}	2.51±0.05^{g}	2.91±0.01^{e}
	28	3.50±0.03^{b}	2.59±0.03^{f}	3.09±0.06^{d}	3.64±0.02^{a}
Texture (Force in N)	0	133.11±0.98^{a}	133.39±0.77^{a}	133.71±0.47^{a}	133.52±0.89^{a}
	8	108.91±0.99^{abcde}	117.72±0.22^{abcd}	129.38±0.90^{ab}	121.16±0.61^{abc}
	16	93.80±0.46^{de}	104.64±1.01^{bcde}	124.90±1.06^{abc}	106.54±0.67^{abcde}
	28	82.60±0.55^{e}	100.75±0.25^{cde}	116.17±0.56^{abcd}	103.76±0.81^{bcde}
Ascorbic acid (mg/100gm)	0	2.90±0.06^{b}	2.91±0.08^{b}	2.89±0.04^{b}	2.96±0.23^{b}
	8	3.21±0.02^{b}	3.12±0.79^{b}	3.10±0.14^{b}	3.13±0.05^{b}
	16	3.61±1.01^{ab}	3.41±0.42^{ab}	3.34±0.34^{ab}	3.57±0.15^{ab}
	28	4.04±0.08^{a}	3.94±0.05^{a}	3.91±0.18^{a}	3.98±0.08^{a}

Note: The mean ± Standard deviation values in rows with different superscripts have significant differences at p<0.05 by DMRT

Total soluble solids (TSS)

The TSS gradually increased in tamarind fruits during storage studies. There is significant difference in TSS among treatments given and storage period. The value of TSS was found to be lower for T_2 followed by T_3 and T_1 at both the temperatures of study. The ripening involves a combination of both synthesis and degradation process. All these process involve inter conversions of an array of carbohydrates [27] and also increase in TSS is attributed to enzymatic conversion of higher polysaccharides such as starches and pectin into simple sugars [28]. Thus, calcium and phenyl acetaldehyde interfere with or slows down the enzymatic activities and ripening process.

Total phenolic content (TPC)

Phenolic compounds are secondary metabolites of plant origin with beneficial biological effects such as antioxidant activity, which is most important. Among the treatments, Increase in TPC was significantly increased during storage studies in different treatments given at different temperatures. At the end of study, Lower phenolic content changes (52.76±0.54 to 105.76±0.84mg GAE/100g at LT and 52.76±0.54 to 110.31±0.10 at RT)was observed in fruits treated with 0.5% calcium chloride followed by 0.25% calcium chloride (53.42±0.37 to 112.15± 0.72mg GAE/100g at LT and 53.42±0.37 to 114.68±0.24 at RT) and phenyl acetaldehyde (53.26±0.23 to 113.33±0.20mg GAE/100g at LT and 53.26±0.23 to 108.38±0.12 at RT). During ripening and storage, there is marked increase in phenolic compounds because of biological activities necessary for development [6]. Thus, calcium and Phenyl acetaldehyde might play role in controlling ripening process.

Table-2 *Quality parameter of Green tamarind during RT storage (29±2°C)*

Parameters	Storage Period (Days)	Treatments and Codes: T0 Control	T1 Calcium Chloride (0.25%)	T2 Calcium Chloride (0.5%)	T3 Phenyl Acetaldehyde (500ppm)
pH value	0	2.58±0.01^{h}	2.58±0.00^{h}	2.59±0.01^{gh}	2.59±0.01^{gh}
	8	2.70±0.04^{d}	2.63±0.00^{ef}	2.62±0.01^{fg}	2.64±0.01^{e}
	16	2.91±0.00^{a}	2.81±0.01^{c}	2.79±0.01^{c}	2.84±0.01^{b}
Titrable Acidity (%)	0	6.32±0.01^{f}	6.24±0.05^{f}	6.22±0.02^{f}	6.05±0.04^{g}
	8	10.13±0.01^{b}	8.42±0.11^{d}	8.43±0.18^{d}	7.58±0.03^{e}
	16	12.14±0.06^{a}	10.23±0.00^{b}	9.98±0.00^{c}	10.18±0.08^{b}
T.S.S (°Bx)	0	9.76±0.06^{g}	9.66±0.12^{g}	9.73±0.06^{g}	9.70±0.17^{g}
	8	19.03±0.12^{c}	16.26±0.06^{e}	14.73±0.06^{f}	14.86±0.06^{f}
	16	21.33±0.64^{a}	19.46±0.06^{b}	18.66±0.06^{d}	19.42±0.03^{b}
Total Phenolics (mgGAE/100gm)	0	52.23±0.94^{i}	53.42±0.37^{i}	52.76±0.54^{i}	53.26±0.23^{i}
	8	85.18±0.98^{h}	89.84±0.79^{e}	86.40±0.43^{gh}	87.36±0.48^{f}
	16	121.81±0.44^{a}	114.68±0.24^{b}	110.31±0.10^{c}	108.38±0.12^{d}
Reducing Sugar (%)	0	0.64±0.20^{g}	0.64±0.01^{g}	0.66±0.02^{g}	0.65±0.01^{g}
	8	0.91±0.01^{d}	0.74±0.01^{f}	0.72±0.02^{f}	0.75±0.01^{e}
	16	1.21±0.01^{a}	0.95±0.00^{c}	0.92±0.01^{d}	0.97±0.01^{b}
Total Sugar (%)	0	8.50±0.06^{g}	8.55±0.02^{g}	8.52±0.06^{g}	8.37±0.12^{g}
	8	12.45±0.08^{d}	9.49±0.06^{ef}	9.34±0.01^{f}	9.62±0.11^{e}
	16	17.15±0.35^{a}	15.06±0.10^{b}	14.15±0.06^{c}	14.98±0.10^{b}
PLW (%)	8	14.14±0.11^{c}	8.58±0.03^{h}	9.95±0.06^{g}	13.05±0.11^{f}
	16	16.56±0.09^{a}	13.21±0.03^{e}	13.88±0.07^{d}	14.89±0.07^{b}
Texture (Force in N)	0	133.11±0.98^{a}	133.39±0.77^{a}	133.71±0.47^{a}	133.52±0.89^{a}
	8	83.30±1.12^{c}	89.06±0.76^{c}	112.91±0.47^{b}	111.73±0.89^{b}
	16	60.30±0.72^{e}	67.06±1.01^{de}	76.24±0.45^{cd}	64.73±0.63^{de}
Ascorbic acid (mg/100gm)	0	2.90±0.06^{b}	2.91±0.08^{b}	2.89±0.04^{b}	2.96±0.23^{b}
	8	3.41±0.02^{ab}	3.38±0.70^{ab}	3.29±0.03^{ab}	3.31±0.23^{ab}
	16	3.75±0.08^{a}	3.63±0.96^{ab}	3.61±0.38^{ab}	3.62±0.03^{ab}

Note: The mean ± Standard deviation values in rows with different superscripts have significant differences at $p<0.05$ by DMRT

Total sugar and reducing sugar content

The results showed that among the treatments, control sample recorded the highest total and reducing sugar percentage content followed by fruits treated with phenyl acetaldehyde, calcium chloride(0.25%) and Calcium chloride(0.5) treated fruits had lowest percentage of Total and reducing sugar content. During ripening, due to enzymatic reactions on pectin and higher polysaccharides and carbohydrate interconversions, there is increase in TSS and total sugar content. In unripe fruit, low levels of reducing sugar content were observed and subsequently, it was increased during ripening. Tamarind fruits pretreated with Calcium salts and Phenyl acetaldehyde showed extension of shelf life of green tamarind with decline in the pools of both total sugar content and also reducing sugar content as important parameters for brown color development in tamarind by non-enzymatic browning [6,28].

Physiological loss in weight (PLW)

The effect of Calcium chloride and phenyl acetaldehyde on weight loss at different storage temperatures is depicted in [Table-1 and 2]. The different treatments with Low temperature and high relative humidity (90-95%) showed better results than RT stored fruits with relative humidity 65-70%. Among LT stored fruits, calcium chloride treated samples showed lower weight loss in comparison to phenyl acetaldehyde treated samples and control. A similar trend on weight loss was observed for RT stored samples also. Weight loss through transpiration is found to be a major cause of quality deterioration in fresh commodity. Weight loss leads to both quantitative loss and qualitative losses in terms of loss in fruit appearance, fruit firmness and nutritional quality attributes that renders less marketability of the commodity. Fruits treatment with Calcium chloride salt solution helps in strengthen the cell wall of fruits and vegetables thereby it stabilizes the membrane system by increasing cross linkage with Calcium-pectate formation, which increase the rigidity of middle lamella and thus preventing the moisture loss due to transpiration [29, 30].

Texture analysis

The results of shear test of tamarind fruits treated with chemical hardening agent-calcium chloride and aroma compound phenyl acetaldehyde showed gradual decrease in firmness with storage time [Table-1 and 2]. The samples treated with higher concentration of calcium chloride (T2-0.5%)showed higher values during storage irrespective of storage temperature. Calcium treated fruits($p<0.05$) retained fruit texture as compared to others, mainly due to the fact that calcium plays an important role in maintaining the cell wall structure by interacting and binding with pectic acids of the cell wall into calcium pectate [31]. Thereby, the cell wall integrity retained when de-esterified pectic acid residues facilitates the cross-bridges between carboxylic acid groups and divalent calcium cations and thus minimizing pectic acid solubilization and also serve as binding agent to stabilize the protein-pectin complexes in middle lamella. Thus, calcium strengthens the cell wall of fruit and also the cell consistency [32-34].

Ascorbic acid content

Ascorbic acid is an important nutrient of natural origin and very sensitive to oxidative degradation during storage [35]. There was no change in ascorbic acid content among the treated samples stored under different temperature conditions. However, it was increased with storage time in these treated samples. The control samples stored at RT showed slight increase in ascorbic acid content than the treated ones. This may be due to enhanced ripening process in control samples stored at room temperature.

Color analysis

The color of fruits and vegetables is one of most appealing attributes that attracts the consumers and also one of the important maturity index. In unripe fruit, the activity of Polyphenol oxidase is responsible for color change in terms of browning of fruit. Among the treatments, the fruits treated with calcium chloride solution (T2-0.5%) showed slight higher L* value than Phenyl acetaldehyde treatment, followed by calcium chloride (T1-0.25%) and the control. The L* values of color decrease drastically during ripening and fruit turns brown. The changes in a* values for chloride solution (T2-0.5% and T1-0.25%) was found to be lower other phenyl acetaldehyde and control. Lastly changes in b* was found to be higher in calcium chloride (T1-0.25%) sample than other treatments. The increase in a* values and decrease in b* values caused the samples more and more towards dark brown color. During initial stage of tamarind pulp development, the low values of total phenolic showing low pigmentation and lack of brown color. When green pods come in contact of air or polyphenol oxidase present in fruit can converts phenols to quinines responsible for brown color. During ripening and storage, there is marked increase in phenolic compounds because of further quinine formation in tamarind fruits [6].

Conclusion

The study reveals that surface hardening of tamarind fruits with calcium chloride dip (0.5% w/v) proved to be ($p<0.05$) effective in maintaining the quality attributes of green tamarind when stored at optimum LT(4 ± 1^0C,90-95% RH) and RT (29 ± 2°C, 65-70%) storage conditions. The results showed that benefit of treatment with 0.5% calcium chloride in terms of retention of fruit firmness, fruit color and total phenolic and other quality parameters, apart from reduction in physiological loss in weight, effective shelf life of tamarind fruits in fresh form up to 28 days at LT and 16 days at RT storage conditions as against 16 days and 8 days respectively in untreated controls when stored under same conditions.

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Author Contributions

Om Prakash- Experimentation collection and analysis of experimental materials and data on storage studies and manuscript preparation.

Amarjeet Kumar-Statistical analysis of experimental data and assistance in manuscript preparation.

Kudachikar VB*-Conceptualisation, planning and co-ordination of studies and manuscript preparation.

Abbreviations

TSS-Total soluble solids
LT- Low Temperature
RT- Room Temperature
T-Treatments
PLW-Physiological loss in weight
TPC-Total phenolic content
GAE-Gallic acid equivalent

Conflict of Interest: None declared

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