Acta Scientific AGRICULTURE (ISSN: 2581-365X)

Volume 9 Issue 2 February 2025

Research Article

Influence of Pre-Harvest and Post-Harvest Interventions on Quality Attributes and Shelf Life of Sapota [Manilkara achras (Mill.) Fosberg] cv. Kalipatti

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Received: January 10, 2025

Published: January 28, 2025

Abstract

The tropical sapota fruit is grown by farmers in several Indian states and is a member of the sapotaceae family. It has a subtle flavor, white latex within the fruit, a distinct sweet taste of digestible sugar between 12-20 percent. Because sapota fruits are perishable, it is essential to research post-harvest treatment and storage techniques in order to extend shelf life. An experiment was conducted at Department of Post-Harvest Technology, Navsari Agricultural University, Navsari, Gujarat, India during 2018 and 2019 to study the influence of pre-harvest sprays and post-harvest dipping treatments on quality and shelf life of sapota [*Manilkara achras* (Mill.) Fosberg] cv. Kalipatti. The experiment was laid out in a Completely Randomized Design comprising of six pre-harvest treatments namely T_1- Control, T_2- GA3 100 ppm, T_3- Novel 1%, T_4- Ca(NO3)2 5000 ppm, T_5- CaCl2 5000 ppm and T_6- Potassium silicate 4 ml/l and post-harvest dipping treatments viz., D1: CaCl2 10000 ppm and D2: GA3 100 ppm. Fruits of sapota were dipped in the months of January during 2018 and 2019 and each treatment was repeated thrice. The results observed that combination of pre-harvest spray of $CaCl_2$ at 5000 ppm with post-dipping of $CaCl_2$ at 5000 ppm recorded the minimizing physiological loss in weight, maximum fruit firmness, TSS, ascorbic acid, total sugars, reducing sugars, non-reducing sugars, days taken to ripening after harvest, shelf life and reducing spoilage at 8th days of storage significant response by different pre-harvest spray and post-dipping treatments of sapota cv. Kalipatti.

Keywords: Sapota; Pre-Harvest Spray; Post-Harvest Dipping; Quality; Shelf Life

Introduction

Sapota [*Manilkara achras* (Mill.) Fosberg] is commonly known as chiku in India. It is an evergreen tree, belonging to the family sapotaceae and is a native of Tropical America. The sapota fruit is a fleshy berry. The fully ripe fruit is delicious and sweet (contains about 12 to 18%) chiefly used for fresh table purpose. Generally, sapota is eaten as fresh fruit and possesses excellent qualities as a dessert fruit. ''Chiku Halwa'' a famous milk based Indian sweet is prepared from sapota shreads [1-3].

'Kalipatti' is the most popular cultivar in Gujarat state of India, accounting about 99 per cent of acreage. Fruits are in oval shape, good quality, mallow flesh, sweet with mild fragrance. It also appears to be the highest yielding cultivar of those tested in India [4] and therefore, will likely continue to be the most widely planted.

One of the challenges being faced by the Indian fruit industry is the enormous losses due to spoilage. The high tropical temperature enhances disease occurrence and deterioration of fruits during storage. The estimated post-harvest losses of perishables are 25 to 30 per cent which may further increase up to 40 percent [5].

Sapota is highly perishable and cannot be stored for longer period at room temperature hence, the farmers are compelled to sell their fruits at reduced rates. The high humidity and temperature accelerate disease development and physico-chemical deterioration of the fruit. It is a climacteric fruit and the main factor which triggers ripening is the rate of ethylene production and rate of respiration after harvest [6]. Ethylene is a natural plant hormone which plays a vital role in the initiation of ripening and has been shown to damage several fruits by accelerating senescence [7,8]. Sapota is one of the tropical fruits which produce highest quantity of ethylene after harvest [9].

Among different elite horticultural practices, growth regulators and other organic and inorganic fertilizers have been advantageously used in the recent time to increase the quantitative and qualitative characters of fruits [10]. Sapota fruits are highly perishable due to their climacteric nature and harvest maturity plays a crucial role in deciding the marketability of climacteric fruits and climacteric fruits are generally characterized by high respiration and ethylene production and chilling sensitivity. Extended fruit storage periods are still not possible, mainly because of the high susceptibility to chilling injury [11].

The problems encountered after harvest in sapota are uneven ripening, weight and quality loss during storage, quick and over ripening and senescing of the edible ripe fruit. Scanty research has been done so far in sapota especially on pre-harvest sprays and post-harvest management to increase shelf life through ripening retardants. Hence, it becomes necessary to find out some suitable pre-harvest spray and post-harvest dip treatments to improve the physico-chemical properties and extend the shelf life which reduce loss of sapota fruit after harvesting.

Gibberellins are the hormones which develop naturally and play a major role in stimulating the reaction of auxins which helps in growth regulation [12]. GA_3 is known to induce mitotic cellular division in fruits and stimulates growth which results in increased size [13]. Novel Organic Liquid Nutrients contains good amount of essential macro-nutrients (N, P, K, Mg and S), micro nutrients (Mn, Cu, Zn and Fe) and secondary metabolites like gibberellins and cytokinin [14]. Calcium being a divalent caution readily enters the apoplast and is bound in exchangeable form to cell wall and exterior surface of the plasma membrane. Nontoxic even at high concentration, it serves as detoxifying agent typing up toxic compounds and maintaining the cation-anion balance in the vacuole [15]. Potassium silicate is a source of highly soluble potassium and silicon and is used in agricultural production system. Potassium is a macro nutrient which is very important for basic physiological function [16]. Hence, the present study was aimed to assess the suitability of different pre-harvest sprays (GA_3, Novel, $Ca(NO_3)_2$, $CaCl_2$) and Potassium silicate and post-harvest dipping (GA_3 and $CaCl_2$) for enhancing and extending quality parameters of sapota cv. Kalipatti fruits.

Materials and Methods

The present experiment was conducted during the year 2018 and 2019 at P.G Laboratory at the Department of Post-Harvest Technology, Navsari Agricultural University, Navsari, Gujarat, India. Uniform trees of sapota cv. Kalipatti were selected for experimentation and treated with respect to fertilizers, irrigation and plant protection measures during the course of investigation as recommended by NAU, Navsari. The experiment was laid out in Completely Randomized Design with factorial concept and two dipping treatments comprising of D1- $CaCl_2$ 10000 ppm and D2- GA3 100 ppm which were repeated thrice. Dipping treatments were imposed of sapota fruits during the months of January (First harvest) - 2018 and 2019.

Preparation of solution

Preparation of $CaCl_2$

For preparation of 10000 ppm $CaCl_2$ solution, 10000 mg $CaCl_2$ was dissolved in 1 litre water. Thus, to prepare 4 liter solution (required for 1 treatment), 40000 mg $CaCl_2$ was used.

Preparation of GA_3

For preparation of 100 ppm GA_3 solution, 100 mg GA_3 was diluted in 95% of alcohol and volume was made to 1 liter with water. Thus, for preparing 4 litre solution (required for 1 treatment), 400 mg GA_3 was utilized.

Selection of fruits

Uniform sized and shaped fruits, healthy, free from any bruising and mechanical injury from the first harvest of the year were selected from harvested lots.

Method and time of dipping

The post-harvest treatments of chemicals sources were applied in the month of January in 2018 and 2019. Fruits were dipped in chemicals solutions for 5 minutes each. The observations pertaining to the quality parameters of the fruits were recorded on alternate days of storage at ambient condition (2nd, 4th, 6th and 8th days). Fruits pulp was homogenized in blender and used for chemical analysis.

Physiological loss in weight (%)

Fruits were weighed on the first day of treatment and their weights were recorded. Subsequently at alternate day intervals, their weights were recorded and the loss in weight was expressed as percentage over the initial weight.

$$\text{PLW (\%)} = \frac{\text{Fresh wt.(g)} - \text{Final wt.(g)}}{\text{Fresh wt (g)}} \times 100$$

Fruit firmness (kg/cm^2)

The firmness of the fruits was tested by means of a table penetrometer. For this purpose, three fruits were selected randomly from the experimental unit. A circular thin size peel of about 1 cm diameter was removed from the fruit surface with the help of the sharp knife. The penetrometer adjusted to zero was pierced in the fruit through the open 30 circular pattern on the fruit surface. The pressure required to penetrate the penetrometer was recorded in kg/cm^2). The average of the three fruits was computed and recorded.

Total soluble solids (°Brix)

TSS was recorded using a hand refractometer. For this purpose, three fruits were selected randomly. The pulp was separated from peel and seeds then homogenized well in electric mixture. The juice was extracted with help of the piece of muslin cloth and tested on hand refractometer and expressed as °Brix. The average of the three fruits was computed and recorded.

Ascorbic acid (mg/100 g pulp)

Titrimetric method described by Ranganna (1986) was adopted for estimation of the ascorbic acid. Ten grams of the homogenized pulp was taken and transferred in 100 ml volumetric flask. The volume was made up with 4 per cent oxalic acid solution. After 30 minutes, the suspension was filtered through Whatman No. 1 filter paper. Before titration the 2,6–Dichlorophenol indophenol (Dye solution) was standardized by titrating against standard ascorbic acid solution and the dye factor was calculated. Five ml of the aliquot was taken from the filtrate and titrated against standardized dye solution through a burette. Titration was continued till light pink colour persisted for 15 seconds [17]. The ascorbic acid content was calculated adopting the following formula,

$$\text{Ascorbic Acid (mg/100g pulp)} = \frac{\text{Titrate x Dye factor x volume made up x 100}}{\text{Aliquot of extract x weight or volume of sample taken for estimation taken for estimation}}$$

Total sugars (%)

For estimation of total sugars, the filtrate obtained in the reducing sugar estimation was used. An aliquot from the filtrate was taken and to one-fifth of its volume, hydrochloride acid (1:1) was added and the inversion was carried out at room temperature for 24 hours. Subsequently, the contents were cooled and neutralized with 40 per cent sodium hydroxide using phenolphthalein as an indicator and the final volume was made up to 100 ml. The solution was filtered and titration was carried out using filtrate as detailed for reducing sugars. The total sugars content was expressed as percentage in terms of invert sugars according to the formula,

$$\text{Total sugar (\%)} = \frac{\text{Glucose eq.of Fehling's solution (0.05)}}{\text{titre}} \times \frac{\text{Total volume made up}}{\text{Weight of pulp taken}} \times \frac{\text{Volume made up after inversion}}{\text{aliquot taken for inversion}} \times 100$$

Reducing sugars (%)

The titrimetric method of Lane and Eynon described by Ranganna (1986) [17] was adopted for estimation of reducing sugar. P. The sugar from thesample was estimated by determining the volume of unknown sugar solution required to completely reduce a measured volume of Fehling's solution. Before using the mixture (1:1) of Fehling's solution A and B was standardized against standard glucose for obtaining glucose equivalent and to arrive at a conversion factor. Procedure Twenty five gram of the pulp was taken in a volumetric flask and two ml of 45 per cent basic lead acetate solution was added for clarification. After 10 minutes, the solution was deleated by adding potassium oxalate crystals in excess and the volume made up to 250 ml with distilled water and filtered through whatman filter paper No. 1. Filtrate was taken into a burrette and titrated against boiling fehlings mixture (5 ml of A and 5 ml of B) till the blue colour faded. Then one to two drops of methylene blue indicator (1%) was incorporated till the appearance of brick red colouron was. At this stage, titration was stopped and titre value was recorded. The percentage of reducing sugar was calculated according to the following formula.

$$\text{Reducing sugars (\%)} = \frac{\text{Glucose eq.(0.05) x Total volume made up}}{\text{Titre value x wt.of pulp}} \times 100$$

Non-reducing Sugars (%)

The value of non-reducing sugars in a sample was obtained by subtracting reducing sugars from total sugars.

Non-reducing sugars (%) = Total sugars – Reducing sugars

Days taken to ripening after harvest

The number of days taken from harvesting to softening of fruits in each treatment was considered as days taken by the fruits to ripen after harvest.

Spoilage (%)

The number of diseased, rotting, smelling rancid and overripe fruits were counted and expressed as percentage over the total number of fruits.

$$\text{Spoilage (\%)} = \frac{\text{Number of spoiled fruits}}{\text{Total number of fruits}} \times 100$$

Shelf life (Days)

The shelf life of fruits was noted by keeping the fruits at room temperature and the days taken from harvesting to optimal eating stage. Fruits surviving for longest duration after harvesting were taken into consideration.

Organoleptic score (1-9 Hedonic Scale)

The sensory evaluation through organoleptic evaluation for assessing the colour, flavour, texture, taste and overall acceptability was done at optimum ripening stage by a panel of judges using 1-9 Hedonic Scale for each character (Table 1).

Table 1: 9 point hedonic scale for organoleptic evaluation.

Sr. No.	Particulars	Hedonic scale rating
1	Dislike extremely	1
2	Dislike very much	2
3	Dislike moderately	3
4	Dislike slightly	4
5	Neither like or dislike	5
6	Like slightly	6
7	Like moderately	7
8	Like very much	8
9	Like Extremely	9

Results and Discussion

Interaction effect of T×D of different parameters on 8th days (Pooled data)

Physiological loss in weight (%)

Pre-harvest spray of $CaCl_2$ at 5000 ppm showed the lowest PLW on 8th day (10.65%) of storage which was statistically at par with $Ca(NO_3)_2$ at 5000 ppm (10.82%). Minimum PLW was noticed on 8th day (11.71%) of storage in treatment D1 ($CaCl_2$ 10000 ppm) in dipping treatments. Treatment combination T_5D_1 showed the lowest PLW on 8th day of storage (10.08%) which was statistically at par with treatment T4D1 (10.19%) (Table 2 and 2a). LW indicates the progress of ripening in climacteric fruits. Higher PLW marks more ripening. In the present investigation, the percent loss in weight of sapota fruits was increased as the storage period advanced irrespective of any treatment. This is attributed to the general loss of water and partial desiccation of the fruits during storage [18]. The present investigation indicates that the physiological loss of fruit was significantly decreased by foliar application of different chemicals. The prime cause of which is retarding action of calcium on the rate of respiration and decay and prevents cellular disintegration by maintaining protein, nucleic acid synthesis and membrane integrity with lower losses of phospholipids and proteins and reduced ion leakages which could be responsible for retention of more moisture and thus, delays senescence [19-21]. The increased weight loss in untreated fruits might be due to the increased storage break down associated with higher respiratory rate as compared to calcium treated fruits. This is in line with earlier reports by Sudha., *et al.* (2007) [22], Bhalerao., *et al.* (2009) [23], Tsomu and Patel (2014) [24], Gondaliya (2016) [25], Desai., *et al.* (2017) [26], Patel., *et al.* (2017) [27], and Anusuya., *et al.* (2019) [29] in sapota; Vishwakarma., *et al.* (2017) [30] in mango; Rajput., *et al.* (2013) [31], Mahajan., *et al.* (2011) [32], Agarwal and Jaiswal (2012) [33], Bhooriya., *et al.* (2018) [34] and El-Dengway., *et al.* (2018) [35] in guava and Yadav and Varu (2013) [36]in papaya.

Table 2: Effect of pre-harvest sprays and post-harvest dipping treatments on PLW, firmness, TSS, ascorbic acid and total sugar of sapota cv. Kalipatti (Pooled).

Treatments		PLW (%)	Firmness (kg/cm^2)	TSS (^{0}Brix)	Ascorbic acid (mg/100 g pulp)	Total sugars (%)
Pre-harvest sprays						
T_1: Control		13.94	1.55	18.93	8.31	18.41
T_2: GA_3 100 ppm		11.38	2.31	23.01	11.85	23.74
T_3: Novel 10000 ppm		13.21	1.77	21.66	9.32	19.84
T_4: $Ca(NO_3)_2$ 5000 ppm		10.82	2.48	23.47	12.74	24.85
T_5: $CaCl_2$ 5000 ppm		10.65	2.52	23.47	12.97	25.20
T_6: Potassium silicate 4000 ppm		12.47	1.98	22.20	10.33	20.64
S.Em. ±		0.10	0.02	0.18	0.10	0.18
C.D. at 5%		0.27	0.06	0.52	0.28	0.52
Post harvest dipping						
D_1: $CaCl_2$ 10000 ppm		11.71	2.21	22.88	11.45	22.75
D_2: GA_3 100 ppm		12.45	2.00	21.50	10.39	21.48
S.Em. ±		0.06	0.01	0.11	0.05	0.11
C.D. at 5%		0.16	0.03	0.30	0.16	0.31
Interaction						
T×D	S.Em. ±	0.14	0.03	0.26	0.14	0.26
	C.D. at 5%	0.37	0.08	0.73	0.40	0.74
C.V. %		2.76	3.23	2.95	3.17	2.99

Table 2a: Interaction effect of T×D on PLW (%) at 8th DAH.

Pooled							
	T_1	T_2	T_3	T_4	T_5	T_6	Mean
D_1	13.79	10.81	13.06	10.19	10.08	12.32	11.71
D_2	14.09	11.95	13.36	11.45	11.22	12.63	12.45
Mean	13.94	11.38	13.21	10.82	10.65	12.47	12.08
	T		D		T × D		
S.Em. ±	0.10		0.06		0.14		
C.D. at 5 %	0.27		0.16		0.37		
C.V. %	2.76						

Table 2b: Interaction effect of T×D on Firmness (kg/cm^2) at 8th DAH.

Pooled							
	T_1	T_2	T_3	T_4	T_5	T_6	Mean
D_1	1.61	2.47	1.82	2.63	2.69	2.04	2.21
D_2	1.50	2.15	1.72	2.32	2.36	1.93	2.00
Mean	1.55	2.31	1.77	2.48	2.52	1.98	2.10
	T		D		T × D		
S.Em. ±	0.02		0.01		0.03		
C.D. at 5 %	0.06		0.03		0.08		
C.V. %	3.23						

Firmness (kg/cm^2)

Pre-harvest spray with $CaCl_2$ at 5000 ppm recorded the maximum firmness on 8th day of storage (2.52 kg/cm^2) which was statistically at par with $Ca(NO_3)_2$ at 5000 ppm (2.48%). $CaCl_2$ at 10000 ppm resulted in the maximum firmness on 8th day of storage (2.21 kg/cm^2). $CaCl_2$ 5000 ppm + $CaCl_2$ 10000 ppm recorded the highest firmness on 8th day (2.69 kg/cm^2) of storage which was on the same bar with $Ca(NO_3)_2$ 5000 ppm and $CaCl_2$ 10000 ppm (2.63 kg/cm^2) (Table 2 and 2b).

Fruit firmness is one of the most crucial factors in determining the post-harvest quality of fruits (Shear, 1975). As the fruit approaches ripening, it becomes soft due to degradation of the cell wall and inter-cellular adhesive substances. Fruit firmness during storage is associated with acceleration of hydrolytic enzymes. Fruit firmness gradually decreased during the storage period, evidently due to advancement of ripening, senescence and break down in the later stages. Probably the added calcium helped to maintain the structure and function of cell wall. Calcium is a constituent of pectate it might have made the middle lamella of fruit cell wall thicker by increased deposition of calcium pectate and thus, maintained the firmness of fruits. Similar results were reported by Sudha., *et al.* (2007) [22], Bhalerao., *et al.* (2009) [23], Tsomu and Patel (2014) [24], Gondaliya (2016) [25], Desai., *et al.* (2017) [27], Patel., *et al.* (2017) and Khanvilkar., *et al.* (2018) in sapota; Mahajan., *et al.* (2011) [32] in guava.

TSS (^{0}Brix)

In pooled analysis, $CaCl_2$ 5000 ppm showed the highest TSS on 8th days of storage (23.87 ^{0}Brix) and it was statistically at par with T_4 $Ca(NO_3)_2$ 5000 ppm (23.47 ^{0}Brix). The same treatment recorded higher values for TSS on 8th day of storage (22.88 ^{0}Brix) in pooled data. Further, in pooled analysis, maximum TSS was registered by T_5D_1 8th day (24.59 ^{0}Brix) and it was statistically at par with T_4D_1 (23.86 ^{0}Brix) (Table 2 and 2c).

Table 2c: Interaction effect of T×D on TSS (^{0}Brix) at 8th DAH.

	Pooled						
	T_1	T_2	T_3	T_4	T_5	T_6	Mean
D_1	21.26	23.42	21.80	23.86	24.59	22.34	22.88
D_2	16.60	22.61	21.53	23.08	23.15	22.07	21.50
Mean	18.93	23.01	21.66	23.47	23.87	22.20	22.19
	T		D		T × D		
S.Em. ±	0.18		0.11		0.26		
C.D. at 5 %	0.52		0.30		0.73		
C.V. %	2.95						

Hydrolysis of starch or conversion of acids to sugar could be the reason for increased TSS with advancement of storage period. At later stages, these sugars along with other organic acids were utilized for respiration at a much faster rate (Wills., *et al*., 1981). Akin results were reported by Bhalerao., *et al.* (2009) [23], Gondaliya (2016) [25], Desai., *et al.* (2017) [27] Patel., *et al.* (2017) and Anusuya., *et al.* (2019) [29] in sapota; Vidya., *et al.* (2014) in mango; Rajput., *et al.* (2013) [31], Mahajan., *et al.* (2011) [32], Agarwal and Jaiswal (2012) [33] and Bhooriya., *et al.* (2018) [34] in guava; and Yadav and Varu (2013) [36] in papaya.

Ascorbic acid (mg/100 g pulp)

the treatment $CaCl_2$ 5000 ppm showed maximum ascorbic acid on 8th day of storage (12.97 mg/100 g pulp) and it was statistically at par with $Ca(NO_3)_2$ 5000 ppm (12.74 mg/100 g pulp).The maximum ascorbic acid on 8th days of storage registered by fruits dipped in $CaCl_2$ 10000 ppm (11.45 mg/100 g pulp).Treatment combination of T_5D_1 recorded the highest ascorbic acid content (13.84 mg/100 g pulp) and it was statistically at par with T_4D_1 (13.53 mg/100 g pulp) on 8th day of storage (Table 2 and 2d).

The ascorbic acid content was higher initially and then subsequently decreases during storage period. The results showed that $CaCl_2$ as a pre-harvest spray at 5000 ppm and post-harvest dip at 10000 ppm had a significant effect on retaining ascorbic acid content in sapota fruit. The decline in ascorbic acid content may be due to the degradation and enzymatic oxidation of L-ascorbic acid to dehydro-ascorbic acid during metabolic process. It was observed

Table 2d: Interaction effect of T×D on Ascorbic acid (mg/100 g pulp) at 8th DAH.

Pooled							
	T_1	T_2	T_3	T_4	T_5	T_6	Mean
D_1	8.57	12.61	9.58	13.53	13.84	10.59	11.45
D_2	8.06	11.09	9.07	11.94	12.10	10.08	10.39
Mean	8.31	11.85	9.32	12.74	12.97	10.33	10.92
	T		D		T × D		
S.Em. ±	0.10		0.05		0.14		
C.D. at 5 %	0.28		0.16		0.40		
C.V. %	3.17						

that higher concentration of $CaCl_2$ delayed the rapid oxidation of ascorbic acid. The present investigation is in conformity with the results reported by Bhalerao., *et al.* (2009) [23], Gondaliya (2016) [25], Desai., *et al.* (2017) [27], Patel., *et al.* (2017), Anusuya., *et al.* (2019) [29] and Kumbar., *et al.* (2019) [38] in sapota; Bhooriya., *et al.* (2011) [34] and Mahajan., *et al.* (2011) [32] in guava and Yadav and Varu (2013) [36] in papaya.

Total sugars (%)

The maximum total sugars was observed with pre-harvest spray of $CaCl_2$ 5000 ppm on 8th day of storage (25.20%) which was statistically at par with $Ca(NO_3)_2$ 5000 ppm (24.85%). The maximum total sugars (22.75%) was registered by fruits dipped in (D_1) $CaCl_2$10000 ppm on 8th day of storage. Treatment combination T_5D_1 revealed the maximum total sugars on 8th day of storage (25.75%) and it was statistically at par with T_4D_1 (25.20%) in pooled analysis. T_5D_1 was also statistically at par with T_2D_1 (25.86%) (Table 2 and 2e).

Accumulation of total sugars during the process of ripening is a consequence of starch hydrolysis. In the present study, accumulation of sugars gradually increased in treated fruits. The increase in total sugar during initial storage period might be due to the hydrolysis of starch into sugar, no further increase occurs and subsequently a decline in total sugar is predictable. The present investigation is in conformity with the results reported by Bhalerao., *et al.* (2009) [23], Gondaliya (2016) [25], Desai., *et al.* (2017) [26], Patel., *et al.* (2017) [27] and Anusuya., *et al.* (2019) [29] and Kumbar., *et al.* (2019) [38] in sapota; Vidya., *et al.* (2014) and Pant and Singh (2018) in mango; Agarwal and Jaiswal (2012) [33], Bhooriya., *et al.* (2018) [34] and El-Dengway., *et al.* (2018) [35] in guava and Yadav and Varu (2013) [36] in papaya.

Table 2e: Interaction effect of T×D on Total sugars (%) at 8th DAH.

Pooled							
	T_1	T_2	T_3	T_4	T_5	T_6	Mean
D_1	18.78	25.86	20.11	25.20	25.75	20.80	22.75
D_2	18.03	21.63	19.58	24.51	24.64	20.49	21.48
Mean	18.41	23.74	19.84	24.85	25.20	20.64	22.11
	T		D		T × D		
S.Em. ±	0.18		0.11		0.26		
C.D. at 5 %	0.52		0.31		0.74		
C.V. %	2.99						

Reducing sugars (%)

In pooled analysis, the highest reducing sugars was observed in pre-harvest spray of (T_5) $CaCl_2$ 5000 ppm on 8th day of storage (11.31%) which was statistically at par with treatment T_4

(11.07%). During pooled analysis, maximum reducing sugar was noted in fruits dipped in $CaCl_2$ at 10000 ppm on 8th day of storage (10.55%). Further, in pooled analysis, maximum reducing sugar was observed on 8th day of storage with combination of pre-harvest and post-harvest dipping T_5D_1 (11.75%) which was statistically at par with T_4D_1 (11.45%) (Table 3 and 3a).

An increase in reducing sugar content by calcium application might be due to lower utilization of sugar in respiration and conversion of starch into sugar, while the subsequent decline was perhaps due to consumption of sugar for respiration during storage and increased rate of starch degradation by amylase activity. Similar findings have been reported by Bhalerao., *et al*. (2009) [23], Gondaliya (2016) [25], Desai., *et al*. (2017) [27], Patel., *et al*. (2017), Anusuya., *et al*. (2019) [29] and Kumbar., *et al*. (2019) [38] in sapota; Agarwal and Jaiswal (2012) [33] and Bhooriya., *et al*. (2018) [34] in guava and Yadav and Varu (2013) [36] and Srinu (2017) [37] in papaya.

Table 3: Effect of pre-harvest sprays and post-harvest dipping treatments on reducing sugars, non-reducing sugars, number of days taken to ripen after harvesting, spoilage and shelf life of sapota cv. Kalipatti.

Treatments		Reducing sugars (%)	Non-reducing sugars (%)	Number of days taken to ripen after harvesting	Spoilage (%)	Shelf life
Pre-harvest sprays						
T_1: Control		8.04	9.46	4.47	24.01	7.43
T_2: GA_3 100 ppm		10.80	12.95	5.67	17.38	9.44
T_3: Novel 10000 ppm		9.58	10.26	4.85	20.22	8.20
T_4: $Ca(NO_3)_2$ 5000 ppm		11.07	14.90	5.94	16.98	9.79
T_5: $CaCl_2$ 5000 ppm		11.31	15.02	5.97	16.70	9.94
T_6: Potassium silicate 4000 ppm		10.08	10.57	5.23	18.78	8.61
S.Em. ±		0.14	0.16	0.05	0.12	0.08
C.D. at 5%		0.40	0.48	0.15	0.34	0.22
Post harvest dipping						
D_1: $CaCl_2$ 10000 ppm		10.55	12.63	5.60	18.32	9.22
D_2: GA_3 100 ppm		9.74	11.76	5.11	19.70	8.59
S.Em. ±		0.08	0.10	0.03	0.07	0.04
C.D. at 5%		0.23	0.29	0.09	0.20	0.13
Interaction						
T×D	S.Em. ±	0.20	0.23	0.07	0.17	0.11
	C.D. at 5%	0.58	0.67	0.22	0.48	0.32
C.V. %		4.76	5.03	3.62	2.19	3.22

Non-reducing sugars (%)

In pooled data, pre-harvest sprays with T_5 recorded maximum non-reducing sugar (15.02%) which was statistically on the same bar with T_4 (14.90%) on 8th day of storage. In pooled analysis, dipping in $CaCl_2$ 10000 ppm showed the maximum non-reducing sugar on 8th day of storage (12.63%). In pooled analysis, treatment combination T_5D_1 registered the highest non-reducing sugar on 8th day of storage (15.25%) which was statistically at par with T_4D_1 (15.08%). Treatment T_5D_1 was also statistically at par with T_2D_1 (14.83%) and T_5D_2 (14.78%) (Table 3 and 3b).

Table 3: Effect of pre-harvest sprays and post-harvest dipping treatments on reducing sugars, non-reducing sugars, number of days taken to ripen after harvesting, spoilage and shelf life of sapota cv. Kalipatti.

Treatments		Reducing sugars (%)	Non-reducing sugars (%)	Number of days taken to ripen after harvesting	Spoilage (%)	Shelf life
Pre-harvest sprays						
T_1: Control		8.04	9.46	4.47	24.01	7.43
T_2: GA_3 100 ppm		10.80	12.95	5.67	17.38	9.44
T_3: Novel 10000 ppm		9.58	10.26	4.85	20.22	8.20
T_4: $Ca(NO_3)_2$ 5000 ppm		11.07	14.90	5.94	16.98	9.79
T_5: $CaCl_2$ 5000 ppm		11.31	15.02	5.97	16.70	9.94
T_6: Potassium silicate 4000 ppm		10.08	10.57	5.23	18.78	8.61
S.Em. ±		0.14	0.16	0.05	0.12	0.08
C.D. at 5%		0.40	0.48	0.15	0.34	0.22
Post harvest dipping						
D_1: $CaCl_2$ 10000 ppm		10.55	12.63	5.60	18.32	9.22
D_2: GA_3 100 ppm		9.74	11.76	5.11	19.70	8.59
S.Em. ±		0.08	0.10	0.03	0.07	0.04
C.D. at 5%		0.23	0.29	0.09	0.20	0.13
Interaction						
T×D	S.Em. ±	0.20	0.23	0.07	0.17	0.11
	C.D. at 5%	0.58	0.67	0.22	0.48	0.32
C.V. %		4.76	5.03	3.62	2.19	3.22

The increase in non-reducing sugar during storage was due to the conversion of starch into sugar. While, decrease in sugar may be due to the consumption of sugar for respiration during storage period. Findings of the present investigation are in line with those obtained by Bhalerao., *et al*. (2009) [23], Desai., *et al*. (2017) [27], Patel., *et al*. (2017) and Kumbar., *et al*. (2019) [38] in sapota; Agarwal and Jaiswal (2012) [33] and Bhooriya., *et al*. (2018) [34] in guava and Srinu (2017) [37] in papaya.

Number of days taken to ripen after harvesting

The maximum number of days taken to ripening (5.97 days) was registered in treatment T5 ($CaCl_2$ at 5000 ppm) which was statistically at par with treatment T_4 [$Ca(NO_3)_2$ at 5000 ppm] (5.94 days) during pooled analysis. There was a significant delay in the number of days taken to ripen after post-harvest dipping in $CaCl_2$ at 10000 ppm (5.60 days) in pooled analysis as compared to GA_3 100 ppm (5.11). The maximum delay in ripening was observed in treatment combination T_5D_1 [$CaCl_2$ 5000 ppm and $CaCl_2$ 10000 ppm] (6.41 days) which was statistically on the same bar with T_4D_1 [$Ca(NO_3)_2$ 5000 ppm and $CaCl_2$ 10000 ppm] (6.37 days) in pooled analysis (Table 3 and 3c).

The fruits treated with pre-harvest spraying and post-harvest dipping application of $CaCl_2$ 5000 ppm and 10000 ppm took significantly maximum number of days for ripening. The delay in ripening of the fruits was due to the fact that application of calcium slowed down the process of ripening by retarding the pre-climacteric respiration rate and ethylene production and through postponement of their climacteric peak a vis a vis control. This change led to reduced degrading metabolism in terms of catalase and Pectin Methyl Esterase activities. The present investigation is in conformity with the results reported by Tsomu and Patel (2014) [24] in sapota and Yadav and Varu (2013) [36] in papaya.

Table 3a: Interaction effect of T×D on Reducing sugars (%) at 8th DAH.

Pooled							
	T_1	T_2	T_3	T_4	T_5	T_6	Mean
D_1	9.12	11.03	9.77	11.45	11.75	10.19	10.55
D_2	6.95	10.57	9.38	10.69	10.86	9.96	9.74
Mean	8.04	10.80	9.58	11.07	11.31	10.08	10.14
	T		D		T × D		
S.Em. ±	0.14		0.08		0.20		
C.D. at 5 %	0.40		0.23		0.58		
C.V. %	4.76						

Table 3b: Interaction effect of T×D on Non- reducing sugars (%) at 8th DAH.

Pooled							
	T_1	T_2	T_3	T_4	T_5	T_6	Mean
D_1	9.66	14.83	10.33	15.08	15.25	10.61	12.63
D_2	9.25	11.06	10.19	14.72	14.78	10.53	11.76
Mean	9.46	12.95	10.26	14.90	15.02	10.57	12.19
	T		D		T × D		
S.Em. ±	0.16		0.10		0.23		
C.D. at 5 %	0.48		0.29		0.67		
C.V. %	5.03						

Table 3c: Interaction effect of T×D on number of days taken to ripen after harvesting.

Pooled							
	T_1	T_2	T_3	T_4	T_5	T_6	Mean
D_1	4.53	5.96	4.97	6.37	6.41	5.38	5.60
D_2	4.40	5.39	4.72	5.51	5.54	5.08	5.11
Mean	4.47	5.67	4.85	5.94	5.97	5.23	5.36
	T		D		T × D		
S.Em. ±	0.05		0.03		0.07		
C.D. at 5 %	0.15		0.09		0.22		
C.V. %	3.62						

Table 3d: Interaction effect of T×D on Spoilage (%) at 8 DAH.

Pooled							
	T_1	T_2	T_3	T_4	T_5	T_6	Mean
D_1	22.77	16.72	19.58	16.34	16.06	18.45	18.32
D_2	25.25	18.05	20.85	17.63	17.33	19.11	19.70
Mean	24.01	17.38	20.22	16.98	16.70	18.78	19.01
	T		D		T × D		
S.Em. ±	0.12		0.07		0.17		
C.D. at 5 %	0.34		0.19		0.48		
C.V. %	2.19						

Spoilage (%)

Pre-harvest spray of $CaCl_2$ at 5000 ppm recorded reduced spoilage (16.70%) which was statistically at par with $Ca(NO_3)_2$ at 5000 ppm (16.98%) on 8th day of storage. Spoilage was recorded lower in the treatment comprising dipping with $CaCl_2$ at 10000 ppm (18.32%) on 8th day of storage. Treatment combination T_5D_1 showed the lowest spoilage on 8th days of storage (16.06%) in pooled data which was statistically at par with treatment combination T_4D_1 (16.34%) (Table 3 and 3d).

Fruits respire even after harvest which leads to deterioration. The storage life and spoilage of fruits are directly related to the rate of respiration. Losses caused by post-harvest handling are generally attributed to decay caused by microorganisms especially fungi. The spoilage per cent in sapota fruits increased as the storage period advanced, irrespective of any treatment. Lower spoilage loss was observed with pre-harvest spray of 5000 ppm and 10000 ppm CaCl2. Calcium treated fruits showed significantly lesser extent of rotting which might be due to the better fruit firmness and calcium content in peel, ultimately resulting in stronger intracellular organization and rigidified cell wall. The present investigation is in conformity with the results reported by Bhalerao., *et al*. (2009) [23], Tsomu and Patel (2014) [24], Gondaliya (2016) [25], Desai., *et al*. (2017) [27], Patel., *et al*. (2017) [27] in sapota; Vishwakarma., *et al*. (2017) [30] in mango and Srinu., *et al*. (2017) [37] in papaya.

Shelf life

In pooled analysis, as treatment T_5 pre-harvest spray registered the maximum shelf life (9.94 days) and it was statistically at par with T4 (9.79 days). Post harvest dipping in CaCl2 10000 ppm resulted in the highest shelf life (9.22 days) during in pooled analysis as compared to GA_3 100 ppm (8.59). A combination of $CaCl_2$ 5000 ppm and $CaCl_2$ 10000 ppm T_5D_1 recorded the highest shelf life (10.27 days) which was statistically at par with T_4D_1 (10.23 days) (Table 3 and 3e).

Table 3e: Interaction effect of T×D on Shelf Life.

	Pooled						
	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**Mean**
D_1	7.95	9.87	8.28	10.23	10.27	8.70	9.22
D_2	6.91	9.02	8.12	9.35	9.62	8.52	8.59
Mean	7.43	9.44	8.20	9.79	9.94	8.61	8.90
	T		D		T × D		
S.Em. ±	0.08		0.04		0.11		
C.D. at 5 %	0.22		0.13		0.32		
C.V. %	3.22						

Fruits subjected to pre-harvest spraying of $CaCl_2$ 5000 ppm coupled with dipping in $CaCl_2$ 10000 ppm had maximum shelf life as compared to other treatments. Calcium treatments gave a better shelf life as it helps in structural integrity and influences cellular organization of both the cell wall and plasma membrane, thereby controlling respiratory breakdown which delays ripening and extends storage life. The binding action of calcium in the cell wall suppresses ethylene production and retard ripening. In the cell walls, calcium serves as a binding agent in the form of calcium pectates. Calcium has received considerable attention in the recent past due to its role in ripening and senescence, increasing firmness, reducing respiration, incidence of physiological disorders, storage rots and extending storage life.

Organoleptic evaluation

Treatment combination of T_5D_1 (pre-harvest spray of $CaCl_2$ 5000 ppm and post-dipping of $CaCl_2$ 1000 ppm) showed maximum score of colour (7.68), Flavour (7.67), Texture (7.66), Taste (8.28) and Overall acceptability (7.80) in mean data (Table 4).

Organoleptic evaluation of the ripened sapota for assessing the quality was done by a panel of fruit scientists who scored the fruits on a 9 points Hedonic scale. The reason behind firmness for longer time and recording higher score for organoleptic characters might be due to chemical treatment. Organoleptic characters like fruit colour, flavour, texture, taste and overall acceptability showed the

Table 4: Effect of pre-harvest sprays and post-harvest dipping on organoleptic test (1-9 Hedonic scale) of sapota cv. Kalipatti.

Treatments	Colour	Flavour	Texture	Taste	Overall acceptability
T_1D_1	5.55	6.46	6.64	6.89	6.39
T_2D_1	6.72	7.41	7.46	7.99	7.63
T_3D_1	6.17	6.72	6.85	7.16	6.73
T_4D_1	7.65	7.58	7.57	8.14	7.73
T_5D_1	7.68	7.67	7.66	8.28	7.80
T_6D_1	6.35	6.88	7.04	7.44	6.93
T_1D_2	4.65	5.00	5.43	5.37	5.11
T_2D_2	6.43	6.98	7.08	7.58	7.02
T_3D_2	5.76	6.60	6.73	7.03	6.53
T_4D_2	6.80	7.24	7.24	7.72	7.32
T_5D_2	7.03	7.37	7.34	7.85	7.42
T_6D_2	6.33	6.85	6.93	7.30	6.86

highest score in fruits treated with pre-harvest spray of $CaCl_2$ 5000 ppm and post-harvest dipping of $CaCl_2$ 10000 ppm which is in accordance with results reported by Bhalerao., *et al*. (2009) [23], Gondaliya., *et al*. (2016) [25] and Kumar., *et al*. (2016) in sapota and Yadav and Varu (2013) [36] in papaya.

Conclusion

Based on the two years investigation, it can be concluded that application of $CaCl_2$ as pre-harvest spray at 5000 ppm coupled with post-harvest dip treatment at 10000 ppm emerged as the best treatment for reducing spoilage, maintaining firmness and extending the shelf life with optimal retention of fruit quality.

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