



GUAVA FRUIT QUALITY AND STORABILITY AS INFLUENCED BY HARVEST MATURITY AND POSTHARVEST APPLICATION OF CALCIUM SALTS

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Abstract

Effect of post harvest treatments with Calcium chloride (1 and 2%) and Calcium nitrate (1 and 2%) on the storage behaviour of guava (cv. Lucknow-49) fruits harvested at mature green and colour turning stages during storage at low temperature were studied. Fruits were packed in newspaper lined corrugated fibre board boxes, cold stored ($10 \pm 1^\circ\text{C}$ and $90 \pm 5\%$ RH) and evaluated after 5, 10, 15 and 20 days for various physico-chemical attributes like PLW, firmness, TSS, acidity, ascorbic acid, pectin content and sensory rating. It was observed that PLW increased, while firmness, acidity and ascorbic acid decreased during storage irrespective of maturity stages and Calcium treatments studied. However, TSS and sensory rating increased upto 10 days with all the treatments except control but subsequently decreased thereafter during storage. However, MG stage fruits exhibited longer shelf life and better fruit quality with all the Calcium treatments compared to CT stage during storage. Similarly, calcium proved beneficial in delaying the ripening related changes in guava fruits, while application of $\text{Ca}(\text{NO}_3)_2$ (2%) recorded a potential shelf life of 23.83 days under cold storage.

Key words : Lucknow-49, mature green (MG), colour turning (CT), calcium chloride (CaCl_2), calcium nitrate ($\text{Ca}(\text{NO}_3)_2$) and physiological loss in weight (PLW).

Introduction

Guava (*Psidium guajava* L.) is one of the most well known edible tree fruits grown widely in more than sixty countries throughout the tropical and sub-tropical regions in the world. In India, it occupies an area of 0.26 million hectares with annual production of 3.66 million tonnes (Saxena and Gandhi, 2014). The fruits are delicious, rich in vitamin 'C', pectin and minerals like calcium, phosphorous and iron. Guava fruits are normally consumed as fresh or processed into several products like jam, jelly, cheese, nectar, paste etc. (Boora, 2012). There is a great demand of guava fruits in both domestic and international markets for fresh and processing purposes. The share of guava in fresh fruit export from India is mere 0.65 per cent which can be further boosted, if fruit is properly handled after harvest to earn more foreign exchange (Mitra *et al.*, 2008). Guava is a

perishable fruit and highly prone to bruising and mechanical injuries. Due to such perishability, control of fruit ripening is fundamental and this generates the necessity to search for new technologies to increase shelf life, reach distant markets and thus improve the marketing process (Mitra *et al.*, 2012). Skin colour is the best maturity index in guava (Mercado-Silva *et al.*, 1998; Kader, 1999 and Asrey *et al.*, 2008) as it could be monitored non-destructively during fruit ripening and storage. Fruits attaining maturity show signs of changing colour from pale green to yellowish green. If the fruit is to be shipped to distant markets, it should be mature, full sized and of firm texture, but without an obvious colour-break on the surface. Fruits for local market can be harvested in a more advanced stage of maturity (Singh, 2007). However, harvesting fruits at appropriate stage of maturity is critical in maintaining the post harvest quality of guava fruits (Azzolini *et al.*, 2004 and Patel *et al.*, 2015). Storage under low temperatures has been

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considered the most efficient method to maintain quality of most fruits and vegetables due to its effects on reducing respiration rate, transpiration, ethylene production, ripening, senescence and disease incidence. On the other hand, enzymatic reactions occur slowly at low temperatures, extending shelf life of perishables (Bron *et al.*, 2005). In climacteric fruits, like most guava varieties, the reduction of temperature delays the climacteric peak and consequently, ripening process (Paull and Chen, 2002). Post harvest applications of calcium salts extend the shelf life of many fruits by maintaining firmness and minimizing the rate of respiration, protein breakdown and disease incidence. They have shown promise in the quality retention of guava fruits also (Singh *et al.*, 1981; Hiwale and Singh, 2003; Tamilselvan and Bal, 2005a & b). Keeping these facts in view, a comprehensive study was carried out at Post Harvest Laboratory, College of Horticulture, Rajendranagar, Hyderabad during the year 2011, on various ripening related changes in guava cultivar 'Lucknow-49' to determine appropriate maturity stage and postharvest treatment for better quality and desirable shelf life under cold storage.

Materials and Methods

Material

Uniform medium sized guava fruits apparently free from diseases and bruises were harvested at two stages of maturity from winter season crop. Mature green stage (MG) is when maximum growth of fruits had been attained and their skin colour changes from dark green to light green; colour turning stage (CT) is when the skin colour turns slightly yellow from light green. They were divided into requisite lots for further handling.

Postharvest treatments, packing and storage

The experiment consisted of three replications and 10 treatment combination. For each replication, thirty fruits (approx. 5 Kg) each for MG and CT stages were selected and subjected to treatment with calcium salts. The fruits were dipped in aqueous solutions of calcium chloride (1 and 2%) and calcium nitrate (1 and 2%) separately each for 5-10 minutes. The control fruits were dipped in tap water for 5-10 minutes and kept for comparison. The surface of the fruit was air dried and thereafter packed in newspaper lined Corrugated Fibre Board (CFB) boxes of 400/300/140 mm size, 3 ply thickness, 4.5 Kg capacity with 5 per cent ventilation. The fruits were stored in walk-in cold chamber (Quality Control Laboratory, ANGRAU, Rajendranagar, Hyderabad) maintained at $10 \pm 1^\circ\text{C}$ temperature and $90 \pm 5\%$ relative humidity.

Analytical methods

Physiological loss in weight (PLW) of fruit was calculated as loss of weight in grams to the initial weight and expressed in percentage. Fruit firmness was measured on opposite sides of the equatorial axis using a stand penetrometer of 0-20 Kg scale (Deccan Techno Corporation). A plunger of 6mm diameter was used for the determination of rupture force and the readings were expressed as kg/cm^2 . The total soluble solids (TSS) were determined by using a hand refractometer, 0-32 scale (Erma, Japan) corrected at 20°C and expressed in $^\circ\text{Brix}$. Acidity and ascorbic acid contents of fruits were estimated by adopting the procedure described by Ranganna (1986), while pectin content was determined by gravimetric method (Sadasivam and Manickam, 1992). The shelf life was determined by recording the number of days the fruits remained in good condition without spoilage in each replication during storage. When the spoilage (over-ripening, skin browning and rotting) of fruits under different treatments exceeded 50 per cent, it was considered as the end of storage period, which was judged by visual scoring. The sensory rating of guava fruits was done by a panel of five semi-trained judges on the basis of nine-point hedonic scale (9 = Like Extremely; 8 = Like Very much; 7 = Like Moderately; 6 = Like Slightly; 5 = Neither Like Nor Dislike; 4 = Dislike Slightly; 3 = Dislike Moderately; 2 = Dislike Very Much; 1 = Dislike Extremely) for fruit appearance and colour, flavour, texture and taste (Amerine *et al.*, 1965). The average of all the above characters was calculated and expressed as overall acceptance. A score of 5.5 and above is considered acceptable for consumer appeal of guava fruits.

Statistical analysis

There were three replications for each treatment and each replicate was comprised of 30 fruits. The experiment was laid out in Completely Randomized Design (CRD) with factorial concept and the data was subjected to analysis as per the procedure outlined by Panse and Sukhatme (1985).

Results and Discussion

Physiological loss in weight (%)

PLW, in general, increased rather slowly in the beginning (0.67%), but at a faster pace later (3.72%) during low temperature storage irrespective of maturity stages and Calcium treatments studied (table 1). MG stage (1.93%) recorded significantly lowest weight loss compared to CT stage (2.30%). The higher weight loss in guava fruits harvested at colour turning stage could be due to higher rates of respiration and transpiration with the advancement of harvest maturity (Elgar *et al.*, 1999).

Of the calcium treatments used, the higher concentration, $\text{Ca}(\text{NO}_3)_2$ -2% showed the lowest weight loss (1.80%), while the highest weight loss was found in control (3.00%). This might be due to the role of calcium on altering the membrane permeability of cell wall and thereby limiting the rate of respiration (Bengerth, 1979). True to these findings, calcium application has been reported to be effective in terms of membrane functionality and integrity maintenance with lower losses of phospholipids and proteins with reduced ion leakage (Lester and Grusak, 1999), which perhaps might be responsible for the lower weight loss in calcium treated fruits in the present study. Many workers, Tamilselvan and Bal (2005b), Jayachandran (2000), Singh (1988) in guava, Gupta *et al.* (1987) in ber and Bharathi and Srihari (2004) in sapota also reported that calcium nitrate (1% or 2%) had effectively reduced weight loss during storage. CaCl_2 treatments were inferior to $\text{Ca}(\text{NO}_3)_2$ in reducing the weight loss of guava fruits. This perhaps might be due to the hygroscopic nature of CaCl_2 , wherein the calcium concentration would have been diluted during uptake, since uptake of calcium was primarily from residues on the fruit surface during storage following dipping (Betts and Bramlage, 1977).

Firmness (Kg/cm²)

Fruit firmness decreased significantly with the advancement of storage period irrespective of maturity stages and calcium treatments studied (table 1). It ranged between 7.02 Kg/cm² on 5th day and 2.25 Kg/cm² on 20th day during storage at low temperature. This loss in firmness is generally associated with ripening might perhaps be due to the activities of cell wall degrading enzymes like, PME and PG (Hobson, 1963). Guava fruits harvested at MG stage (5.12 Kg/cm²) maintained higher firmness values compared to those of CT stage (4.04 Kg/cm²) fruits throughout storage. Possibly, in early maturity stages the enzymes related to softening were still not completely synthesized and activated (MacRae *et al.*, 1989). Of all the Calcium treatments studied, fruits treated with $\text{Ca}(\text{NO}_3)_2$ at higher concentration (2%) significantly registered higher fruit firmness (4.94 Kg/cm²). The results are in agreement with the findings of Abbott *et al.* (1989) in apple, Tamilselvan and Bal (2005b) and Goutam *et al.* (2010) in guava and Mahajan *et al.* (2008) in plum, where Calcium nitrate has been found to be effective in increasing the firmness of fruits might be due to the effect of delaying senescence, preserving cellular organization and retarding respiration rate (Faust and Shear, 1972). Further, it was observed that higher concentration (2%) of both the calcium salts maintained significantly higher firmness than their corresponding

lower concentration (1%) in the present study. Akhtar *et al.* (2010) in loquat and Navjot *et al.* (2010) and Gupta *et al.* (2011) in peach showed that higher concentrations of CaCl_2 (3% and 6%, respectively) retained significantly higher firmness than lower concentrations. On the other hand, control (3.92 Kg/cm²) fruits experienced faster loss of firmness accompanied by desiccation and browning of surface tissue during storage thereby leading to excessive softening and shriveling of fruits.

TSS (°Brix)

Independent of maturity stages at which guava fruits were harvested, total soluble solids did not differ significantly during low temperature storage (table 2). The TSS content of guava fruits increased upto 10 days and 15 days of storage respectively with CT and MG stages and later declined towards the end. Hydrolysis of starch or conversion of acids to sugars 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). However, there were significant differences in the TSS contents of guava fruits with respect to Calcium treatments and control. Initially, the fruits under control obtained a prominent peak in TSS on 10th day of storage but showed sudden decrease thereafter and the rate of reduction in TSS was much higher than calcium treated fruits. Calcium treatments (nitrate and chloride) did not considerably affect the TSS content of guava fruit, rather had some preserving effect on TSS due to retardation of ripening. The TSS content was more in control upto 5 days of storage than all the calcium treated fruits, but it remained in low levels from 10th day till the end of storage. However, the TSS was higher for a period of 20 days in low temperature storage with calcium nitrate treatments (1% and 2%) suggesting the use of either of the concentrations to record more TSS than in control fruits during low temperature storage and the results are in corroboration with the findings of Goutam *et al.* (2010) in guava and Mahajan *et al.* (2008) in plum.

Acidity

The acidity decreased gradually during storage at low temperature irrespective of maturity stages and calcium treatments studied (table 2) *i.e.* from 5th day (0.64%) to a minimum of 0.48 per cent on 20th day of storage and this decrease might be due to rapid utilization of organic acids in the respiratory process (Wills *et al.*, 1981). It was observed that guava fruits harvested at MG stage (0.59%) maintained higher levels of acidity throughout storage compared to CT stage (0.54%).

Table 1 : Effect of maturity stages and calcium treatments on PLW (%) and firmness (Kg/cm²) of guava fruits cv. Lucknow-49 at low temperature storage.

Maturity stages	Storage period (Days)									
	PLW (%)					Firmness (Kg/cm ²)				
	5	10	15	20	Mean	5	10	15	20	Mean
Mature Green stage (S1)	0.61 ^a	1.37 ^a	2.32 ^a	3.43 ^a	1.93^a	7.66 ^a	5.71 ^a	4.32 ^a	2.79 ^a	5.12^a
Colour Turning stage (S2)	0.74 ^b	1.76 ^b	2.66 ^b	4.00 ^b	2.30^b	6.38 ^b	4.84 ^b	3.22 ^b	1.71 ^b	4.04^b
Calcium treatments										
Calcium chloride - 1% (T1)	0.65 ^{bcd}	1.44 ^{bcd}	2.31 ^{cd}	3.54 ^{cd}	1.99^d	6.90 ^{cd}	5.22 ^{cd}	3.68 ^{cd}	2.32 ^{cd}	4.53^d
Calcium chloride - 2% (T2)	0.60 ^{abc}	1.39 ^{abc}	2.22 ^{abc}	3.45 ^{bc}	1.91^{bc}	7.20 ^{ab}	5.45 ^{ab}	4.05 ^{ab}	2.59 ^{ab}	4.82^b
Calcium nitrate - 1% (T3)	0.57 ^{ab}	1.35 ^{ab}	2.15 ^{ab}	3.37 ^{ab}	1.86^{ab}	7.08 ^{bc}	5.35 ^{bc}	3.88 ^{bc}	2.41 ^{bc}	4.68^c
Calcium nitrate - 2% (T4)	0.52 ^a	1.28 ^a	2.11 ^a	3.31 ^a	1.80^a	7.35 ^a	5.59 ^a	4.17 ^a	2.68 ^a	4.94^a
Control (T5)	1.02 ^c	2.39 ^c	3.66 ^c	4.93 ^c	3.00^e	6.57 ^c	4.77 ^c	3.08 ^c	1.27 ^c	3.92^e
Mean	0.67^a	1.57^b	2.49^c	3.72^d		7.02^a	5.28^b	3.77^c	2.25^d	

	S.Em. ±	C.D (0.05)	S.Em±	C.D (0.05)
Maturity Stages (MS)	0.013	0.036	0.024	0.068
Calcium Treatments (CT)	0.020	0.057	0.038	0.107
Storage Period (SP)	0.018	0.051	0.034	0.096
MS × CT	0.029	NS	0.054	0.152
MS × SP	0.026	0.072	0.048	0.136
CT × SP	0.040	0.114	0.076	0.215
MS × CT × SP	0.057	NS	0.108	NS

Among the different calcium treatments studied, 1 and 2 per cent calcium nitrate concentrations were found almost equally effective in maintaining higher acidity during low temperature storage. The higher acidity in fruits treated with calcium might be due to decreased hydrolysis of organic acids and subsequent accumulation of these acids which are oxidized at a slower rate because of decreased respiration (Gupta *et al.*, 2011). In general, fruits with higher acidity obtained higher shelf life as reported by Padmavathi (1999) in banana and Ahmed (1998) in mango. Reasonable levels of acidity were maintained upto 10th day of low temperature storage in untreated fruits. However the loss in acidity was much higher in the latter half of storage, wherein the fruits tend to be insipid in taste in control.

Ascorbic acid (mg/100g)

Independent of maturity at harvest and post harvest application of calcium salts, the ascorbic acid content of guava fruits declined continuously during storage at low temperature (table 3) from 5th day (214.93 mg/100g) to 20th day (167.00 mg/100g). Similar reports were made in guava by Dashora (2001). During ripening, oxidizing enzymes like ascorbic acid oxidase, peroxidase, catalase and polyphenol oxidase are responsible in decreasing the

ascorbic acid content of fruits (Mapson, 1970). In addition, the presence of phenolics in the fruit cells may help to maintain the ascorbic acid content. Initially at harvest, the ascorbic acid content was more in guava fruits picked at colour turning stage compared to mature green stage, but during storage, MG stage (201.52 mg/100g) recorded higher levels of ascorbic acid than CT stage (186.71 mg/100g). It was found that guava fruits treated with calcium nitrate and calcium chloride were significantly better in the retention of ascorbic acid compared to control, might be attributed to the slow rate of oxidation in the respiration process. The results are in similarity with the findings of Jain and Mukherjee (2011) in mango, Goutam *et al.* (2010) in guava, Torres *et al.* (2009) in atemoya and Siddiqui and Gupta (1988) in ber. In contrast to the above findings, Singh *et al.* (1981) in guava and Rajkumar *et al.* (2005) in papaya reported an increase in the ascorbic acid content with Calcium application during storage.

Pectin content (%)

The pectin content of guava fruits decreased significantly during low temperature storage with respect to maturity stages and calcium treatments studied (table 3) *i.e.* from 5th day (0.66%) to a minimum of 0.43 percent on 20th day of storage. The pectin content is related to

Table 2 : Effect of maturity stages and calcium treatments on TSS (⁰Brix) and acidity (%) of guava fruits cv. Lucknow-49 at low temperature storage.

Maturity stages	Storage period (Days)									
	TSS (⁰ Brix)					Acidity (%)				
	5	10	15	20	Mean	5	10	15	20	Mean
Mature Green stage (S1)	11.19 ^b	11.98 ^{ab}	12.02 ^a	10.74 ^a	11.48	0.67	0.63	0.57	0.51	0.60^b
Colour Turning stage (S2)	11.96 ^a	12.14 ^a	11.38 ^b	10.07 ^b	11.39	0.61	0.57	0.53	0.46	0.54^a
Calcium treatments										
Calcium chloride - 1% (T1)	11.35 ^{bcde}	11.98 ^{abcde}	11.70 ^{abcd}	10.35 ^{bcd}	11.34^{cd}	0.63 ^a	0.59 ^{ab}	0.55 ^b	0.49 ^b	0.56^b
Calcium chloride - 2% (T2)	11.52 ^{bc}	12.06 ^{abc}	11.82 ^{abc}	10.47 ^{abc}	11.47^{bc}	0.63 ^a	0.61 ^{bc}	0.55 ^b	0.49 ^b	0.57^{bc}
Calcium nitrate - 1% (T3)	11.46 ^{bcd}	12.15 ^{ab}	11.99 ^{ab}	10.66 ^{ab}	11.56^{ab}	0.64 ^{ab}	0.61 ^{bc}	0.58 ^c	0.51 ^{bc}	0.58^{bcd}
Calcium nitrate - 2% (T4)	11.60 ^{ab}	12.20 ^a	12.08 ^a	10.88 ^a	11.69^a	0.66 ^{bc}	0.62 ^{bcd}	0.58 ^c	0.53 ^{cd}	0.60^{de}
Control (T5)	11.94 ^a	12.02 ^{abcd}	10.88 ^e	9.69 ^e	11.13^e	0.63 ^a	0.57 ^a	0.50 ^a	0.41 ^a	0.52^a
Mean	11.57^{bc}	12.08^a	11.69^b	10.41^d		0.64^d	0.60^c	0.55^b	0.49^a	

	S.Em±	C.D (0.05)	S.Em±	C.D (0.05)
Maturity Stages (MS)	0.046	NS	0.003	0.007
Calcium Treatments (CT)	0.073	0.206	0.004	0.011
Storage Period (SP)	0.065	0.184	0.004	0.010
MS × CT	0.103	NS	0.006	NS
MS × SP	0.092	0.260	0.005	NS
CT × SP	0.146	0.411	0.008	0.022
MS × CT × SP	0.207	NS	0.011	NS

the firmness of the fruit, where a decreasing firmness or softening of the fruits causes a very marked decrease in protopectin and an increase in soluble pectin (Hansen, 1966). Mature green stage (0.57%) fruits obtained highest pectin content than colour turning stage (0.54%) for 20 days of storage. But the quantity of pectin was higher in case of guava fruits picked at CT stage during the initial days of storage. However, a rapid decline in pectin content was observed during the latter half of storage. Increase in externally applied calcium concentration resulted in increased deposition and uptake of calcium by the fruits and thus maintaining higher contents of pectin during storage than control. The breakdown of pectin was much higher in untreated fruits (0.49%) especially after 10 days of low temperature storage. Application of calcium salts might have minimized the activity of pectin degrading enzymes in guava fruits during storage (Singh and Chauhan, 1981; Jayachandran *et al.*, 2005).

Sensory rating (9 point scale)

The effect of maturity stages and post harvest application of calcium salts showed significant differences with respect to fruit appearance and colour, flavour, texture, taste and overall acceptability of guava fruits during low temperature storage (fig. 1). The highest

scores were attributed to the fruits harvested at mature green stage and rated as 'like moderately' to 'like very much', over colour turning stage. However, peak scores were obtained with the CT stage fruits on 10th day of storage. Sensory scores for fruit appearance and colour, flavour and taste increased until ripe stage, *i.e.* on 10th day and 15th day of storage with CT and MG stages respectively and then tend to decline till the end of storage. On the other hand, fruit texture gradually decreased with both the stages of maturity during storage. Gaur and Bajpai (1982) reported that organoleptic scores of pink stage tomato fruits were found superior over the red ripe fruits during storage.

The organoleptic quality with respect to appearance and colour, flavour, texture, taste and overall acceptance of guava fruits was more in all the calcium treated fruits compared to control. However, guava fruits treated with Ca(NO₃)₂ at both the concentrations, scored highest after 15 days of storage for all the sensory parameters except texture and were rated as 'Like moderately' to 'Like very much'. In spite of delayed loss in skin greenness in Ca(NO₃)₂ treated fruits, the organoleptic scores for fruit appearance and colour were higher because they were free from shrivelling and dark spots, which were noticed

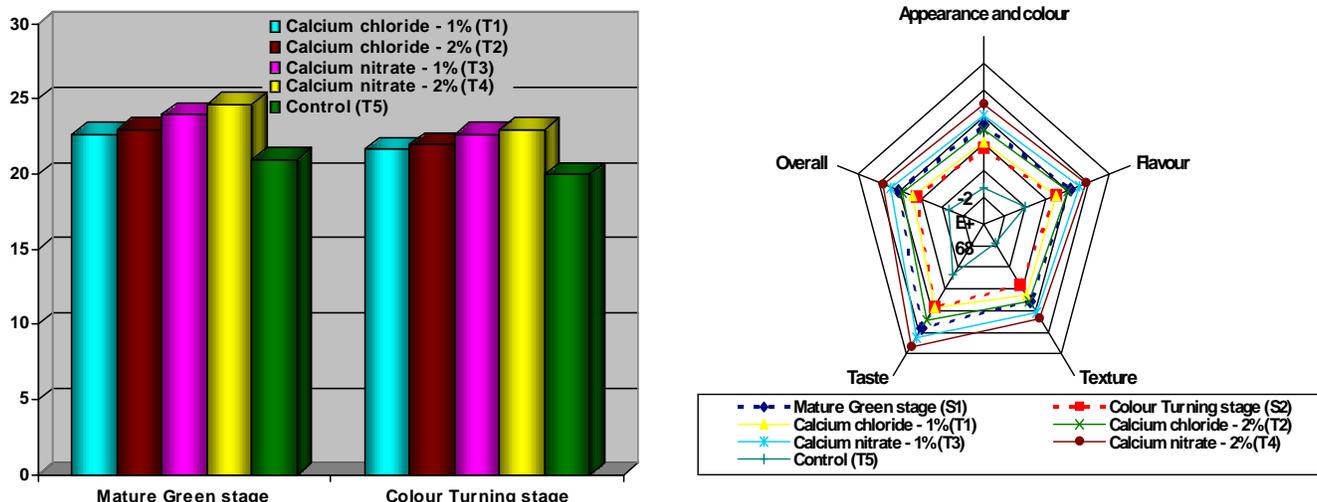


Fig. 1 : Effect of maturity stages and calcium treatments on shelf life (days) and sensory rating (9 point scale) for appearance and colour, flavour, texture, taste and overall acceptance of guava fruits cv. Lucknow-49 at low temperature storage.

Table 3 : Effect of maturity stages and calcium treatments on ascorbic acid (mg/100g) and pectin content (%) of guava fruits cv. Lucknow-49 at low temperature storage.

Maturity stages	Storage period (Days)									
	Ascorbic acid (mg/100g)					Pectin content (%)				
	5	10	15	20	Mean	5	10	15	20	Mean
Mature Green stage (S1)	220.35	212.85	198.67	174.19	201.52^a	0.65 ^b	0.61 ^a	0.56 ^a	0.46 ^a	0.57^a
Colour Turning stage (S2)	209.51	199.17	178.36	159.82	186.71^b	0.67 ^a	0.61 ^a	0.49 ^b	0.41 ^b	0.54^b
Calcium treatments										
Calcium chloride - 1% (T1)	213.24	197.16	182.06	163.44	188.98^d	0.67 ^{abc}	0.62 ^{bcd}	0.53 ^{bc}	0.43 ^{bc}	0.56^{cd}
Calcium chloride - 2% (T2)	215.88	212.00	190.77	166.38	196.25^c	0.69 ^a	0.64 ^{ab}	0.54 ^{ab}	0.45 ^{ab}	0.58^{ab}
Calcium nitrate - 1% (T3)	221.18	216.15	198.81	170.22	201.59^b	0.68 ^{ab}	0.63 ^{abc}	0.53 ^{bc}	0.43 ^{bc}	0.57^{bc}
Calcium nitrate - 2% (T4)	226.81	221.44	205.49	183.84	209.39^a	0.69 ^a	0.65 ^a	0.56 ^a	0.47 ^a	0.59^a
Control (T5)	197.55	183.29	165.46	151.15	174.36^e	0.58 ^d	0.51 ^e	0.47 ^d	0.38 ^d	0.49^e
Mean	214.93^a	206.01^b	188.52^c	167.00^d		0.66^a	0.61^b	0.53^c	0.43^d	

	S.Em±	C.D (0.05)	S.Em±	C.D (0.05)
Maturity Stages (MS)	0.868	2.442	0.002	0.007
Calcium Treatments (CT)	1.373	3.862	0.004	0.011
Storage Period (SP)	1.228	3.454	0.004	0.010
MS × CT	1.942	5.461	0.006	NS
MS × SP	1.737	NS	0.005	0.014
CT × SP	2.746	NS	0.008	0.022
MS × CT × SP	3.883	NS	0.011	NS

under CaCl₂ treatments due to which they are dull in appearance and scored lower than the former ones. Calcium nitrate applied as post harvest treatment to guava fruits in the present study was superior in organoleptic quality than calcium chloride, due to the fact that they obtained higher TSS and sugars, as evidenced by the results. The observed difference between the two calcium

salts as a result of high relative humidity in low temperature storage, wherein the Ca⁺ concentration may be diluted from the fruit surface in CaCl₂ treated fruits due to the hygroscopic nature of CaCl₂ (Betts and Bramlage, 1977). Singh (1988), Singh *et al.* (2007) and Goutam *et al.* (2010) also found that calcium nitrate treated guava fruits rated higher sensory score and

maintained optimum quality for longer period. On contrary, in a study conducted by Randhawa *et al.* (2009) and Jawandha *et al.* (2009) in ber and Gupta *et al.* (2011) in peach, reported that calcium chloride was found superior to calcium nitrate for organoleptic quality. However, explaining the discrepancies among the results from various studies is rather difficult.

Shelf life (days)

In the present study, it was observed that all the Calcium treatments were significantly superior over control in extending shelf life of guava fruits with both the maturity stages during storage at low temperature (fig. 1). However, MG stage recorded extended shelf life than CT stage which might be due to a shift in climacteric peak because of delayed physiological and biochemical changes during ripening and the delay in these changes being more prominent in cold storage. Tandon *et al.* (1989) also reported that larger and more mature fruits of guava had shorter shelf life and hence could be transported only to shorter distances. The fruits picked at the later stage of maturity (CT stage) were spoiled due to over-ripening and rotting with minimum consumer appeal during storage. The data is quiet similar to those of Barua *et al.* (2010) in tomato, Narayana and Mustaffa (2007) and Gonge *et al.* (2014) in banana, wherein a decrease in shelf life is noticed with the advancement of maturity. Low temperature could be an added advantage for much higher storage life of both the treated and untreated fruits during storage. Among the Calcium salts studied in the present experiment, post harvest application of calcium nitrate irrespective of concentrations was found to be superior over calcium chloride in extending the storage life of guava fruits. The observed difference between the two calcium salts might be due to differential absorption of calcium by the fruit from different sources (Bhagwan, 1998). Calcium nitrate (2%) treated guava fruits could be stored for a period of 23.83 days as against control (20.50 days) and the extension of storage life by calcium could possibly be due to delay in the early onset of senescence. Similar reports were also made by Singh *et al.* (1981) and Jayachandran (2000) in guava, Bharathi and Srihari (2004) in sapota and Mahajan *et al.* (2008) in plum. The combination treatments of maturity stages and Calcium salts were also proved effective in extending the storage life of guava fruits. MG stage in combination with calcium nitrate treatments were the best in recording higher storage life among all the other treatment combinations. However, Jawandha *et al.* (2009) reported that calcium treated ber fruits at colour break stage prolonged the storage life for 20 days under low temperature.

Conclusion

The stage of maturity or ripeness at harvest and postharvest treatments with calcium salts had a significant effect on fruit quality and shelf life of guava fruits during cold storage ($10\pm 1^{\circ}\text{C}$ and $90\pm 5\%$ RH). However, maturity stage at harvest strongly influenced the ripening behaviour of guava fruits as evidenced by changes in firmness, acidity, ascorbic acid and pectin contents. It is concluded that freshly harvested MG guava fruits treated with (2.0%) can be stored for more than 24 days during cold storage with moderately acceptable fruit quality. It seems to be the best option if the fruits are to be transported to distant markets or stored for longer period. Furthermore, it may be suggested that CT stage guava fruits should not be stored for more than 10 days at $10\pm 1^{\circ}\text{C}$, because rapid loss in quality occurs at that temperature and the fruits become over-ripe and mealy with poor consumer acceptability.

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