IJPPHT
e ISSN-2231-6426
Volume 6 | Issue 2 | December, 2015 | 128-143
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International Journal of Processing and Post Harvest Technology

RESEARCH PAPER
DOI: 10.15740/HAS/IJPPHT/6.2/128-143

Post harvest physiological and biochemical changes in guava (cv. LUCKNOW-49) fruits harvested at two stages of maturity during low temperature storage

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■ **Research chronicle : Received :** 25.08.2015; **Revised :** 15.10.2015; **Accepted :** 17.11.2015

SUMMARY :

The present investigation was carried out at Post Harvest Laboratory, College of Horticulture, Rajendranagar, Hyderabad during Nov.-Dec. (2010 and 2011). Skin colour, fruit firmness, pectin content, pectin methyl esterase (PME) activity, respiration and ethylene evolution rates were monitored during cold storage (10±1°C and 90±5% RH) of guavas (cv. LUCKNOW-49) harvested at two stages of maturity, mature green (maximum growth of fruits is attained and skin colour changes from dark green to light green) and colour turning (skin colour turns slightly yellow from light green) treated with naphthalene acetic acid (100 and 200 ppm), gibberellic acid (150 and 300 ppm) and benzyl adenine (25 and 50 ppm). Skin colour (Hunter 'L', 'a' and 'b') increased progressively, while fruit firmness and pectin content decreased consistently with the advancement of storage period. Activity of cell wall degrading enzyme, PME declined gradually till the fruits became ripe, but increased in the over-ripe stage. Likewise, respiration and ethylene production rates also exhibited similar pattern of increase coinciding with ripe stage followed by a decline later. However, the peak in respiration rate was preceded by maximum ethylene production in guava during storage at 10±1^{0}C. Mature green (MG) stage fruits showed promising results in delaying the physiological and biochemical changes compared to colour turning (CT) stage and among the treatments, fruits treated with BA (50 ppm) exhibited longer shelf-life and acceptable fruit quality during cold storage.

KEY WORDS : Lucknow-49, Mature green, Colour turning, NAA, GA_3, BA, PME, CO_2 and C_2H_4

How to cite this paper : Deepthi, V. Phani and Sekhar, R. Chandra (2015). Post harvest physiological and biochemical changes in guava (cv. LUCKNOW-49) fruits harvested at two stages of maturity during low temperature storage. *Internat. J. Proc. & Post Harvest Technol.*, **6** (2) : 128-143.

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, phosphorus and iron. Guava fruits are used

as fresh as well as for making jam, jelly, 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 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). Research has revealed that the post harvest application of various growth regulators like auxins, gibberellins and cytokinins on various fruit crops have enhanced their shelf-life and reduced the spoilage and improved the fruit quality by delaying the onset of senescence during storage (Dhoot *et al*., 1984; Rajput *et al*., 1992 and Patel *et al*., 1993). Auxins can counteract the stimulatory effect of ethylene or abscissic acid on senescence and hence, are prominent as endogenous growth regulators. Cytokinins and gibberellins are also implicated to a greater or lesser extent as senescence retardants (Sacher, 1973). Keeping these facts in view, a comprehensive study was carried out on various physiological and biochemical changes in guava cultivar 'Lucknow-49' to determine appropriate maturity stage and postharvest treatment for better quality and desirable shelf-life under cold storage.

EXPERIMENTAL METHODS

Uniform medium sized guava fruits apparently free from diseases and bruises were harvested at two stages of maturity. 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 fruits were dipped in aqueous solutions of different concentrations of Naphthalene acetic acid (100 and 200 ppm), Gibberellic acid (150 and 300 ppm) and Benzyl adenine (25 and 50 ppm) 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 ± 1^{0}C temperature and 90±5 per cent relative humidity.

Analytical methods :

Skin colour of guava fruits was instrumentally determined by using a colourimetric spectrophotometer (Model: Colorflex XE, Hunter Lab, West Virginia, USA) and expressed in Hunter scale ('L', 'a', and 'b'). The readings were made at three equidistant points of the equatorial axis of fruits. Hunter 'L' data indicates lightness of the object, range between 0 (black) and 100 (white). The 'a' data represents red and green: positive values indicate red colour with +60 being the maximum, while negative values indicate green colour with -60 being the maximum and 0 is considered neutral. Similarly, 'b' represents yellow and blue: positive values are yellow, while negative values are blue and 0 is considered neutral (McGuire, 1992). 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. Pectin content and PME activity were determined as per the method described by Sadasivam and Manickam (1992). Fruit samples of known weight and volume were enclosed in hermetically sealed PVC containers (500ml capacity), fitted with silicon Teflon septum, for an hour. The probe of the gas analyzer was inserted through the septum and the gas concentrations of O_2 (%), CO_2 (%) and C_2H_4 (ppm) were recorded directly from the display screen. Respiration rate was determined using O_2/CO_2 gas analyzer (Model: Checkpoint EN, PBI Dansensor, Denmark) and expressed in $mLCO_2$/kg/h (Singh, 2006). Ethylene production rates were analyzed using a battery powered portable ethylene meter (Model: Ethan, Bioconservacion, SA) with 0-100 ppm range and expressed in μLC_2H_4/kg/h (Singh, 2006). The storage 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 overall organoleptic rating of the 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).

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).

EXPERIMENTAL FINDINGS AND ANALYSIS

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Skin colour (Hunter L, a, b) :

During storage at low temperature, the Hunter 'L' and 'b' values showed an increasing trend, whereas the negative Hunter 'a' value decreased with increase in days of storage irrespective of maturity stages and chemical treatments indicating a progressive development of skin colour of guava fruits from green to yellow (Tables 1a, 1b and 1c). There was a significant improvement of yellowness (Hunter 'b') value and skin luminosity or lightness (Hunter 'L') value in both MG and CT stages of guava fruits during low temperature storage. However, the complete loss of skin greenness (Hunter 'a') and yellow colour development was much earlier in guava fruits harvested at colour turning stage during storage. The results were in accordance with Paull and Goo (1983). Thereafter, sudden fall in 'L' and 'b' values was noticed with colour turning stage fruits. This decrease was due to over-ripening and rapid senescence, where the fruits turned dull and yellowish brown in colour. The decrease in negative Hunter 'a' value (greenness) was accompanied by the increase in yellowness (Hunter 'b' value) value. The loss in skin greenness during ripening perhaps may be due to increased activities of chlorophyll degrading enzymes including chlorophyllase, chlorophyll oxidase and peroxidase (Jain *et al*., 2001).

It was also observed that colour development is closely associated with climacteric peak with both the maturities at harvest (Tables 5 and 6). The colour development which started prior to the onset of climacteric was completed at the peak climacteric stage. These colour changes clearly indicate the physiological changes associated with ripening which are desirable in climacteric fruits like guava to improve its marketability. A gradual increase in Hunter values ('L', 'a', 'b') were also observed in other cultivars of guava at three stages of maturity *viz*., mature green, green yellow and yellow (Mercado-Silva *et al*., 1998; Soares *et al*., 2007 and Pradeep *et al*., 2014) and mango (Kudachikar *et al*., 2001) during ripening and storage. The delay in chlorophyll degradation and yellow colour development in fruits harvested at early stage of maturity could be due to the enzymes related to ripening have not been fully synthesized or even inactivated (Lalel *et al*., 2003). Narayana and Mustaffa (2007) also pointed out that banana fruits at 100 per cent maturity exhibited colour change faster than fruits of lower maturity. In a study conducted by Basulto *et al*. (2009), maximum gas

Table 1a: Effect of maturity stages and growth regulators on skin colour 'Hunter L' (lightness) of guava fruits cv. LUCKNOW-49 at low temperature storage

	Storage period (Days)									
	2010					2011				
	5	10	15	20	Mean	5	10	15	20	Mean
Maturity stages										
Mature green stage (S_1)	36.97	40.73	46.79	53.35	44.46^{a}	38.01	41.14	46.67	53.64	44.86^{a}
Colour turning stage (S_2)	44.91	48.96	54.65	59.57	52.02^{b}	45.50	48.37	54.96	59.79	52.15^{b}
Chemical treatments										
Naphthalene acetic acid - 100ppm (T_1)	43.14	46.11	51.42	58.85	49.88^{ef}	43.45	45.90	51.91	58.74	50.00^{ef}
Naphthalene acetic acid - 200ppm (T_2)	41.75	45.55	50.80	57.71	48.95^{de}	42.81	44.85	51.10	57.21	48.99^{de}
Gibberellic acid - 150ppm (T_3)	40.57	44.47	49.87	56.36	47.82^{cd}	41.72	44.09	49.91	56.86	48.14^{cd}
Gibberellic acid - 300ppm (T_4)	37.44	41.45	47.95	53.47	45.08^{a}	38.42	42.18	48.15	53.94	45.67^{a}
Benzyl adenine - 25ppm (T_5)	40.16	43.74	49.38	55.84	47.28^{bc}	40.44	43.00	49.22	55.44	47.02^{abc}
Benzyl adenine - 50ppm (T_6)	38.53	42.10	48.91	54.96	46.12^{ab}	39.39	43.00	48.57	54.57	46.38^{ab}
Control (T_7)	45.01	50.52	56.71	58.04	52.57^{g}	46.05	50.27	56.83	60.24	53.35^{g}
Mean	40.94^{a}	44.85^{b}	50.72^{c}	56.46^{d}		41.75^{a}	44.76^{b}	50.81^{c}	56.71^{d}	
			S.E.±		C.D (P=0.05)		S.E.±		C.D (P=0.05)	
Maturity stages (MS)			0.301		0.844		0.302		0.847	
Chemical treatments (CT)			0.563		1.579		0.565		1.585	
Storage period (SP)			0.426		1.194		0.427		1.198	
MS × CT			0.797		NS		0.800		NS	
MS × SP			0.602		NS		0.604		NS	
CT × SP			1.127		NS		1.131		NS	
MS × CT × SP			1.593		NS		1.599		NS	

NS= Non-significant

Table 1b: Effect of maturity stages and growth regulators on skin colour 'Hunter a' (greenness) of guava fruits cv. LUCKNOW-49 at low temperature storage

	Storage period (Days)									
	2010					2011				
	5	10	15	20	Mean	5	10	15	20	Mean
Maturity stages										
Mature green stage (S_1)	-8.64^{a}	-5.55^{a}	-2.24^{a}	2.53^{a}	-3.47^{a}	-8.68^{a}	-5.53^{a}	-2.23^{a}	2.58^{a}	-3.46^{a}
Colour turning stage (S_2)	-6.58^{b}	-3.52^{b}	-0.55^{b}	4.10^{b}	-1.64^{b}	-6.56^{b}	-3.55^{b}	-0.53^{b}	4.13^{b}	-1.63^{b}
Chemical treatments										
Naphthalene acetic acid - 100ppm (T_1)	-7.46^{de}	-4.45^{e}	-1.49^{f}	3.51^{f}	-2.47^{f}	-7.50^{f}	-4.40^{f}	-1.53^{f}	3.52^{ef}	-2.48^{f}
Naphthalene acetic acid - 200ppm (T_2)	-7.59^{cd}	-4.69^{d}	-1.74^{e}	3.31^{de}	-2.68^{e}	-7.62^{de}	-4.66^{de}	-1.75^{e}	3.34^{de}	-2.67^{e}
Gibberellic acid - 150ppm (T_3)	-7.75^{c}	-4.69^{d}	-2.00^{cd}	3.13^{cd}	-2.83^{d}	-7.77^{cd}	-4.81^{cd}	-2.00^{cd}	3.20^{d}	-2.84^{d}
Gibberellic acid - 300ppm (T_4)	-8.11^{a}	-5.17^{a}	-2.37^{a}	2.39^{a}	-3.31^{a}	-8.12^{a}	-5.19^{a}	-2.32^{a}	2.47^{a}	-3.29^{a}
Benzyl adenine - 25ppm (T_5)	-7.98^{ab}	-4.98^{abc}	-2.20^{abc}	2.98^{c}	-3.04^{c}	-7.94^{abc}	-4.90^{bc}	-2.21^{ab}	2.97^{c}	-3.02^{c}
Benzyl adenine - 50ppm (T_6)	-7.98^{ab}	-5.10^{ab}	-2.22^{ab}	2.57^{ab}	-3.18^{b}	-8.03^{ab}	-5.08^{ab}	-2.20^{abc}	2.69^{b}	-3.15^{b}
Control (T_7)	-6.39^{f}	-2.66^{f}	2.24^{g}	5.32^{g}	-0.37^{g}	-6.35^{g}	-2.75^{g}	2.32^{g}	5.31^{g}	-0.37^{g}
Mean	-7.61^{a}	-4.53^{b}	-1.40^{c}	3.32^{d}		-7.62^{a}	-4.54^{b}	-1.38^{c}	3.36^{d}	
			S.E.±		C.D (P=0.05)		S.E.±		C.D (P=0.05)	
Maturity stages (MS)			0.019		0.052		0.019		0.052	
Chemical treatments (CT)			0.035		0.097		0.035		0.098	
Storage period (SP)			0.026		0.074		0.026		0.074	
MS × CT			0.049		NS		0.049		NS	
MS × SP			0.037		0.104		0.037		0.105	
CT × SP			0.070		0.195		0.070		0.196	
MS × CT × SP			0.098		0.275		0.099		0.277	

NS= Non-significant

Table 1c: Effect of maturity stages and growth regulators on skin colour 'Hunter b' (yellowness) of guava fruits cv. LUCKNOW-49 at low temperature storage

	Storage period (Days)									
	2010					2011				
	5	10	15	20	Mean	5	10	15	20	Mean
Maturity stages										
Mature green stage (S_1)	20.37^{a}	23.66^{a}	29.00^{a}	35.32^{a}	27.09^{a}	20.15^{a}	23.06^{a}	27.58^{a}	34.08^{a}	26.22^{a}
Colour turning stage (S_2)	29.12^{b}	32.57^{b}	37.82^{b}	38.00^{b}	34.38^{b}	26.76^{b}	31.02^{b}	34.73^{b}	39.49^{b}	33.00^{b}
Chemical treatments										
Naphthalene acetic acid - 100ppm (T_1)	26.68^{ef}	30.33^{ef}	36.64^{ef}	36.71^{abcdef}	32.59^{f}	25.26	28.80	33.32	38.71	31.52^{f}
Naphthalene acetic acid - 200ppm (T_2)	25.70^{de}	28.56^{de}	34.84^{de}	36.07^{abc}	31.29^{de}	24.00	27.53	31.39	37.65	30.14^{de}
Gibberellic acid - 150ppm (T_3)	23.44^{bc}	26.31^{bc}	31.64^{bc}	36.17^{abcd}	29.39^{bc}	21.77	25.39	28.78	35.84	27.94^{bc}
Gibberellic acid - 300ppm (T_4)	20.30^{a}	23.89^{a}	29.39^{a}	35.53^{ab}	27.28^{a}	20.32	23.37	28.73	34.41	26.71^{a}
Benzyl adenine - 25ppm (T_5)	24.62^{cd}	27.62^{cd}	33.66^{cd}	35.39^{a}	30.32^{cd}	22.97	26.59	30.98	36.80	29.33^{d}
Benzyl adenine - 50ppm (T_6)	22.45^{b}	25.35^{ab}	29.60^{ab}	36.58^{abcde}	28.49^{b}	20.34	24.44	28.88	35.01	27.17^{ab}
Control (T_7)	30.04^{g}	34.72^{g}	38.12^{g}	40.19^{g}	35.77^{g}	29.55	33.19	36.03	39.08	34.46^{g}
Mean	24.75^{a}	28.11^{b}	33.41^{c}	36.66^{d}		23.46^{a}	27.04^{b}	31.16^{c}	36.78^{d}	
			S.E.±		C.D. (P=0.05)			S.E.±		C.D. (P=0.05)
Maturity stages (MS)			0.195		0.548			0.189		0.529
Chemical treatments (CT)			0.365		1.024			0.353		0.990
Storage period (SP)			0.276		0.774			0.267		0.749
MS × CT			0.517		1.449			0.500		NS
MS × SP			0.391		1.095			0.378		1.059
CT × SP			0.731		2.049			0.707		NS
MS × CT × SP			1.034		2.897			0.999		2.801

NS= Non-significant

production (CO_2 and C_2H_4) coincided with the point at which the average a* value of papaya fruits nearly reached zero (*i.e*. no green remains and red begins to appear). However, Brito and Narain (2002) observed the change in skin colour of sapota fruits from green colour in mature stage to brown colour in ripe stage.

The yellow colour development was rapid with the untreated fruits and complete degreening was noticed after 10 days of storage. All the growth regulator treatments (BA, GA_3 and NAA) had significantly slowed down the yellow colour development of guava fruits during low temperature storage upto 15 days. The delay in colour development could be due to the increase in inhibitory effect of these chemicals on the enzymes responsible for chlorophyll degradation. It was observed that the higher concentration of gibberellic acid (300ppm) showed highest negative Hunter 'a' values on all the days of storage with comparatively lower skin lightness and yellowness (Hunter 'L' and 'b') values compared to all the other treatments studied. The effect of GA_3 seems to be mainly on colour development, although other aspects of ripening processes were also affected. Similar delay in colour development with GA_3 at concentrations more than 150ppm was also pointed out by Patel *et al*. (1993) in guava and Pila *et al*. (2010) in tomato. However, natural ripening comparable to colour development could not have been facilitated with GA_3 at 300ppm concentration because higher concentration might have inhibited the degreening process as reported by Sakhale *et al*. (2009). Saha (1971) also contended that gibberellic acid treatments at 200 ppm or higher concentrations resulted in delayed colour development in guava. Fruits treated with BA at both the concentrations (50ppm and 25ppm) also showed higher retention of green colour upto 15th day of low temperature storage. Green colour retention in fruits treated with BA and NAA have also been reported in guava (Jayachandran *et al*., 2007 and Dhoot *et al*., 1984) and mango (Ahmed, 1998) during prolonged storage.

Firmness :

The present experimental findings revealed that

firmness of guava fruits decreased significantly with the advancement of storage period irrespective of maturity stages and growth regulators studied (Table 2). Firmness ranged between 7.04 and 7.03 kg/cm^2 on 5th day and 2.34 and 2.32 kg/cm^2 on 20th day of low temperature storage. The loss in firmness during ripening can be attributed to the gradual increase in the enzyme activities resulting in the degradation of lignin and pectin constituents of the cell wall that make the fruit soft (Mattoo *et al*., 1975). Fruit firmness is closely associated with the maturity stage. The progressive softening in guava fruits while ripening is attributed to changes in pectic constituents (Pal and Selvaraj, 1979). Fruits at more advanced maturity stages showed lower fruit firmness compared to those harvested at earlier stages in guava (Mercado-Silva *et al*., 1998 and Sharma, 2006) and papaya (Bron and Jacomino, 2006). The present experimental results are in close conformity with the above findings. Guava fruits harvested at mature green stage maintained higher firmness values compared to those of colour turning stage fruits throughout storage. Possibly, in early maturity stages the enzymes related to softening were still not completely synthesized and activated. MacRae *et al*. (1989) and Johnston *et al*. (2002) also observed the slower initial softening in kiwis and apples, respectively harvested at early maturity stages.

Guava fruits treated with higher concentrations of all the growth regulators studied were much firmer than their corresponding lower concentrations. However, BA at 50ppm could effectively retain maximum firmness (4.99 and 4.96 kg/cm^2), while the least was observed with control (3.92 and 3.92 kg/cm^2). The firmness in benzyl adenine treated fruits was probably maintained by lowering the rate of respiration, which might also reflect on inhibition of ethylene production and inactivation of pectolytic enzymes (Jayachandran, 2000).

Pectin content :

From the present experimental studies, pectin content of guava fruits was influenced by storage period irrespective of maturity stages and growth regulator

Table 2 : Effect of maturity stages and growth regulators on firmness (kg/cm^2) of guava fruits cv. LUCKNOW-49 at low temperature storage

	Storage period (Days)									
	2010					2011				
	5	10	15	20	Mean	5	10	15	20	Mean
Maturity stages										
Mature green stage (S_1)	7.64	5.74	4.39	2.89	5.17^a	7.64	5.75	4.35	2.88	5.15^a
Colour turning stage (S_2)	6.45	4.89	3.30	1.79	4.11^b	6.42	4.88	3.27	1.77	4.08^b
Chemical treatments										
Naphthalene acetic acid - 100ppm (T_1)	6.88	5.17	3.68	2.27	4.50^f	6.89	5.13	3.66	2.23	4.48^{ef}
Naphthalene acetic acid - 200ppm (T_2)	6.96	5.25	3.81	2.39	4.60^{de}	6.96	5.21	3.76	2.34	4.56^e
Gibberellic acid - 150ppm (T_3)	7.07	5.36	3.88	2.47	4.69^d	7.07	5.38	3.91	2.47	4.71^d
Gibberellic acid - 300ppm (T_4)	7.18	5.48	4.13	2.59	4.85^{bc}	7.18	5.49	4.05	2.59	4.83^{bc}
Benzyl adenine - 25ppm (T_5)	7.31	5.56	4.10	2.64	4.90^{ab}	7.23	5.59	4.04	2.65	4.88^{ab}
Benzyl adenine - 50ppm (T_6)	7.36	5.64	4.25	2.72	4.99^a	7.31	5.64	4.19	2.70	4.96^a
Control (T_7)	6.56	4.74	3.09	1.30	3.92^g	6.56	4.78	3.08	1.28	3.92^g
Mean	7.04^a	5.31^b	3.85^c	2.34^d		7.03^a	5.32^b	3.81^c	2.32^d	
			S.E.±		C.D. (P=0.05)		S.E.±		C.D. (P=0.05)	
Maturity stages (MS)			0.017		0.048		0.019		0.053	
Chemical treatments (CT)			0.032		0.089		0.035		0.099	
Storage period (SP)			0.024		0.068		0.027		0.075	
MS × CT			0.045		0.126		0.050		0.141	
MS × SP			0.034		0.096		0.038		0.106	
CT × SP			0.064		0.179		0.071		0.199	
MS x CTx SP			0.090		NS		0.100		NS	

NS=Non-significant

treatments. It showed a progressive decline on successive days of storage (Table 3). The pectin content is related to 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). The quantity of pectin was higher in case of guava fruits picked at colour turning of maturity during the initial days of storage. However, a rapid decline in pectin content was observed during the later half of storage. Guava fruits picked at mature green stage obtained significantly higher levels of total pectin than colour turning stage during 20 days of low temperature storage. Shastri and Shastri (1975), Dhillon *et al*. (1987) and Ramchandra (1995) reports on guava lend support for the findings of the present investigation, which have been later confirmed with the reports of Selvaraj *et al*. (1998) and Jain *et al*. (2001), where a continuous decrease in total pectin was noticed from green mature stage to ripe stage during ripening in guava and even pointed out that mature green fruits could be used as a good source for preparing commercial pectin. Results revealed that guava fruits treated with BA at both the concentrations, 25ppm (0.58 and 0.58 %) and 50ppm (0.58 and 0.57 %) obtained higher pectin content compared to GA_3 and NAA treatments. A similar kind of observation was reported in the findings of Jayachandran *et al*. (2007) in guava with increased pectin content as a result of BA application. It was also noticed that the treatment BA at 50ppm recorded longer shelf-life with increased firmness maintained higher levels of pectin. Hence, the retention of total pectin during storage in the present study can be attributed to the aforesaid reason.

Pectin methyl esterase activity :

In the present study, there were considerable fluctuations in the pectin methyl esterase activity of treated and untreated fruits with both the maturity stages and chemical treatments studied at low temperature storage (Table 4). It was noted in higher levels in guava fruits picked at colour turning stage when compared to mature green stage during storage at low temperature. The enzyme activity was fairly high at immature stage,

Table 3 : Effect of maturity stages and growth regulators on pectin content (% calcium pectate) of guava fruits cv. LUCKNOW-49 at low temperature storage

	Storage period (Days)									
	2010					2011				
	5	10	15	20	Mean	5	10	15	20	Mean
Maturity stages										
Mature green stage (S_1)	0.65	0.61	0.56	0.45	0.57[a]	0.64	0.60	0.54	0.42	0.55
Colour turning stage (S_2)	0.66	0.61	0.50	0.40	0.54[b]	0.67	0.61	0.51	0.40	0.55
Chemical treatments										
Naphthalene acetic acid - 100ppm (T_1)	0.65	0.60	0.51	0.41	0.54[de]	0.65	0.60	0.51	0.39	0.54[e]
Naphthalene acetic acid - 200ppm (T_2)	0.65	0.61	0.53	0.42	0.55[cd]	0.66	0.61	0.52	0.39	0.54[e]
Gibberellic acid - 150ppm (T_3)	0.66	0.62	0.54	0.43	0.56[bc]	0.67	0.62	0.53	0.40	0.55[cd]
Gibberellic acid - 300ppm (T_4)	0.68	0.63	0.54	0.44	0.57[ab]	0.68	0.63	0.53	0.42	0.56[bc]
Benzyl adenine - 25ppm (T_5)	0.67	0.64	0.56	0.45	0.58[a]	0.68	0.63	0.53	0.43	0.57[ab]
Benzyl adenine - 50ppm (T_6)	0.68	0.64	0.56	0.45	0.58[a]	0.70	0.64	0.54	0.44	0.58[a]
Control (T_7)	0.59	0.52	0.47	0.37	0.49[f]	0.59	0.53	0.48	0.39	0.50[f]
Mean	0.65[a]	0.61[b]	0.53[c]	0.42[d]		0.66[a]	0.61[b]	0.52[c]	0.41[d]	
			S.E.±		C.D. (P=0.05)			S.E.±		C.D. (P=0.05)
Maturity stages (MS)			0.002		0.005			0.002		NS
Chemical treatments (CT)			0.004		0.010			0.003		0.009
Storage period (SP)			0.003		0.008			0.002		0.007
MS × CT			0.005		NS			0.004		0.012
MS × SP			0.004		0.011			0.003		0.009
CT × SP			0.007		NS			0.006		0.017
MS × CT × SP			0.010		0.029			0.009		NS

NS= Non-significant

decreased considerably at mature stage, again increased when the fruits became ripe and was maximum at the over-ripe stage (Pal and Selvaraj, 1979). The results are more or less in accordance with the above findings. The PME activity was much higher on 10th day and 5th day and then decreased upto 15th day and 10th day of storage in guava fruits picked at MG and CT stages, respectively, followed by an increase towards the end. This delay in the rise of enzyme activity of both the stages could be due to the delay in ripening as a result of low temperature storage. It was also reported that the enzyme activities are much more dependent on storage temperature of the fruits (Pantastico *et al.*, 1975). Randhawa *et al*. (1987) in pear, Mondal *et al*. (2009) and Sharma *et al*. (2012) in guava and Singh and Pathak (2008) in mango also reported a similar increase in the activity of PME upto CT stage, but was followed by a decline upto OR stage. Hence, it is clearly understood from the present study, that the PME activity was maximum during early ripening (CT) stage and tend to decline upto ripe stage and again increased during senescence or final stage of ripening. This decline in PME activity was initiated with ripening and reached to a minimum shortly before the peak in respiration and ethylene production as reported by Awad and Young (1980) in avocado. A decrease in PME activity during ripening of guava fruit was earlier reported by (Shastri and Shastri, 1975; Selvaraj *et al*., 1998).

The peak PME activity was observed on 5th day with the treated and on 20th day with untreated fruits during storage. Post harvest application of benzyl adenine and gibberellic acid had slowed down and delayed the activity of the enzyme during storage. The reduction in the activity of PME was comparably lower with BA treated guava fruits. This reduction in the enzyme activities as a result of BA application could be due to delayed ripening and senescence. More or less similar kinds of results were reported by Dashora (2001) in guava fruits. GA_3 was also reported to reduce the relative activity of catalase and PME enzymes with concomitant decline in pectin breakdown in guava (Hiwale and Singh, 2003) and sapota (Gautam and Chundawat, 1989). However, NAA at both the concentrations used in this study failed to exert

Table 4: Effect of maturity stages and growth regulators on pectin methyl esterase activity (PME.Units × 10^2) of guava fruits cv. LUCKNOW-49 at low temperature storage

	Storage period (Days)									
	2010					2011				
	5	10	15	20	Mean	5	10	15	20	Mean
Maturity stages										
Mature green stage (S_1)	0.79^{a}	1.14^{b}	0.51^{a}	0.79^{a}	0.81^{a}	0.79^{a}	1.15^{b}	0.52^{a}	0.81^{a}	0.82^{a}
Colour turning stage (S_2)	1.15^{b}	0.60^{a}	0.82^{b}	1.02^{b}	0.90^{b}	1.15^{b}	0.59^{a}	0.82^{b}	1.04^{b}	0.90^{b}
Chemical treatments										
Naphthalene acetic acid - 100ppm (T_1)	0.99^{bcd}	0.93^{efg}	0.66^{bcd}	0.90^{cde}	0.87^{de}	1.00^{ef}	0.92^{cde}	0.66^{cde}	0.92^{cde}	0.88^{ef}
Naphthalene acetic acid - 200ppm (T_2)	0.98^{bc}	0.92^{def}	0.65^{abc}	0.89^{bcd}	0.86^{cd}	0.99^{de}	0.91^{bcd}	0.66^{cde}	0.91^{cd}	0.87^{de}
Gibberellic acid - 150ppm (T_3)	0.98^{bc}	0.91^{cde}	0.65^{abc}	0.89^{bcd}	0.86^{bcd}	0.99^{de}	0.91^{bcd}	0.65^{bcd}	0.90^{bc}	0.86^{cd}
Gibberellic acid - 300ppm (T_4)	0.97^{ab}	0.90^{bcd}	0.64^{ab}	0.88^{bc}	0.85^{bc}	0.98^{bcd}	0.90^{bc}	0.64^{abc}	0.90^{bc}	0.85^{bc}
Benzyl adenine - 25ppm (T_5)	0.97^{ab}	0.89^{bc}	0.63^{a}	0.87^{ab}	0.84^{ab}	0.97^{abc}	0.89^{b}	0.63^{ab}	0.89^{b}	0.84^{ab}
Benzyl adenine - 50ppm (T_6)	0.95^{a}	0.88^{b}	0.63^{a}	0.85^{a}	0.83^{a}	0.96^{ab}	0.89^{b}	0.62^{a}	0.86^{a}	0.83^{a}
Control (T_7)	0.95^{a}	0.67^{a}	0.83^{e}	1.06^{f}	0.88^{ef}	0.95^{a}	0.67^{a}	0.84^{f}	1.07^{f}	0.88^{efg}
Mean	0.97^{d}	0.87^{b}	0.67^{a}	0.91^{c}		0.97^{d}	0.87^{b}	0.67^{a}	0.92^{c}	
			S.E.±		C.D. (P=0.05)		S.E.±		C.D. (P=0.05)	
Maturity stages (MS)			0.002		0.006		0.002		0.005	
Chemical treatments (CT)			0.004		0.011		0.003		0.009	
Storage period (SP)			0.003		0.008		0.002		0.007	
MS × CT			0.006		0.015		0.005		0.013	
MS × SP			0.004		0.012		0.004		0.010	
CT × SP			0.008		0.022		0.007		0.018	
MS × CT × SP			0.011		0.031		0.009		0.026	

significant influence on reduction in PME activity and was comparable with control.

Respiration and ethylene production rate:

There was a remarkable difference in the respiratory and ethylene production rates of treated and untreated fruits with both the maturity stages during storage at low temperature (Tables 5 and 6). In the present study, the peak rates of CO_2 production were observed on 10th day and 15th day of storage, respectively, with CT stage and MG stage fruits thus indicating normal ripening. This delay in respiratory peak with the early harvested fruits may be attributed to delayed colour changes. Previous studies with two guava cultivars (Safeda and Sardar) have demonstrated a respiration peak at yellow hard stage and decline thereafter in ripe stage (Selvaraj *et al*., 1998 and Killadi *et al*., 2007). Fruits harvested at mature green stage showed a typical climacteric respiration and ethylene production pattern at 10^0C, as was reported by Mercado-Silva *et al*. (1998) in guava cv. 'MEDIA CHINA'. However, Azzolini *et al*. (2004) pointed out that 'Pedro Sato' guavas exhibited a gradual increase in respiration and ethylene production, while maximum respiratory activity, as well as ethylene production was observed when the fruits were already ripe. In general, the colour and quality changes coincided with the peak in respiration rate *i.e.* on 10th day and 15th day of low temperature storage with guava fruits harvested at CT and MG stages, respectively. The growth regulators not only suppressed the respiratory climacteric, but also delayed it. Among them, benzyl adenine (50 ppm) was found effective in delaying and suppressing the respiratory activity of guava fruits during storage but found insignificant with gibberellic acid treatments, presumably because of its effect on inhibition of ripening and senescence processes. Similar inhibition of respiration in guava with application of growth regulators used in the present study was also reported in the findings of Hiwale and Singh (2003).

Guava fruits at MG stage showed highest C_2H_4 production than CT stage for a period of 20 days during low temperature storage. A clear evidence of increased ethylene content from green to colour turning stage was reported in guava (Selvaraj *et al*., 1998), which was later confirmed by Mondal *et al*. (2008) and Simrat (2009)

Table 5 : Effect of maturity stages and growth regulators on respiration rate (mLCO_2/kg/h) of guava fruits cv. LUCKNOW-49 at low temperature

	Storage period (Days)									
	2010					2011				
	5	10	15	20	Mean	5	10	15	20	Mean
Maturity stages										
Mature green stage (S_1)	20.33	28.12	53.02	33.85	33.83[a]	20.05	27.40	52.25	33.48	33.30[a]
Colour turning stage (S_2)	31.14	51.83	38.18	32.00	38.29[b]	29.35	53.64	36.97	34.20	38.54[b]
Chemical treatments										
Naphthalene acetic acid - 100ppm (T_1)	26.68	40.68	47.31	33.21	36.97[def]	24.92	41.30	45.99	35.82	37.01[ef]
Naphthalene acetic acid - 200ppm (T_2)	25.70	39.38	46.84	33.57	36.37[cde]	24.00	39.95	46.06	35.15	36.29[cde]
Gibberellic acid - 150ppm (T_3)	23.44	37.97	46.97	33.28	35.42[bc]	22.97	39.42	45.82	34.88	35.77[bcd]
Gibberellic acid - 300ppm (T_4)	24.62	38.95	47.16	33.27	36.00[cd]	21.77	38.81	46.05	35.17	35.45[abc]
Benzyl adenine - 25ppm (T_5)	22.45	37.13	46.43	33.58	34.89[ab]	20.34	38.44	45.44	35.36	34.89[ab]
Benzyl adenine - 50ppm (T_6)	19.30	36.69	45.60	35.20	34.20[a]	19.82	37.87	45.89	34.75	34.58[a]
Control (T_7)	37.93	49.05	38.91	28.38	38.56[g]	39.11	47.86	37.03	25.74	37.43[efg]
Mean	25.73[a]	39.98[c]	45.60[d]	32.93[b]		24.70[a]	40.52[c]	44.61[d]	33.84[b]	
			S.E.±		C.D. (P=0.05)		S.E.±		C.D. (P=0.05)	
Maturity stages (MS)			0.208		0.576		0.220		0.611	
Chemical treatments (CT)			0.389		1.078		0.412		1.143	
Storage period (SP)			0.294		0.815		0.312		0.864	
MS × CT			0.550		1.525		0.583		1.617	
MS × SP			0.416		1.153		0.441		1.222	
CT × SP			0.778		2.157		0.825		2.286	
MS × CT × SP			1.101		3.050		1.166		3.233	

where the peak for C_2H_4 production in guava fruit occurred at the half-ripe or colour break stage, thus, leading to early softening and spoilage. The results are in close conformity with the above findings, wherein a marked rise in C_2H_4 production was observed on 5th day and 10th day of storage, respectively, with colour turning and mature green stage fruits. The fruits in control did not show any prominent peak for ethylene production. This indicates that untreated fruits had already completed climacteric rise in ethylene production before 5th day of storage. The lowest ethylene production was observed with GA_3 at 300ppm due to restricted ripening as evident from the results. The application of GA_3 possibly retarded the production of ethylene in the fruit tissue having a direct bearing with the biochemical changes involved in the process of ripening. The inhibitory effect of benzyl adenine on ethylene production in the present study may be attributed to their free radical scavenging properties. The results are in agreement with those of Ahmed (1998) in mango, who also showed delayed and reduced peaks for CO_2 and C_2H_4 production in BA treated fruits during storage. Lieberman *et al*. (1977) postulated that auxins and cytokinins appear to play significant role in the control of ethylene production by plant tissues. Further, they also advocated that gibberellic acid had less influence in suppressing ethylene production in the tissues of apple, tomato and avocado during maturation and senescence.

Storage life :

Fruit maturity at harvest substantially influenced the storage life of guava fruits at low temperature storage (Table 7). With respect to the effect of low temperature in extending the storage life, it was observed that guava fruits harvested at both the stages could be held at 10 ± 1^0C for a period of 20 days without affecting the fruit quality. The present experimental findings indicate that mature green stage significantly extended storage life than colour turning stage which might be due to a shift in climacteric peak and exhibited slow physiological and biochemical changes during ripening and the delay in these changes being more prominent in storage at low temperature. Tandon *et al*. (1989) also reported that larger and more mature fruits of guava had shorter shelf-life and hence, could be transported to only shorter distances. However,

Table 6: Effect of maturity stages and growth regulators on ethylene production rate (µLC_2H_4/kg/h) of guava fruits cv. LUCKNOW-49 at low temperature storage

	Storage period (Days)									
	2010					2011				
	5	10	15	20	Mean	5	10	15	20	Mean
Maturity stages										
Mature green stage (S_1)	6.78	9.73	4.98	2.95	6.11^{b}	6.87	9.79	5.10	2.97	6.18^{b}
Colour turning stage (S_2)	9.49	4.99	3.23	1.33	4.76^{a}	9.49	5.12	3.05	1.57	4.81^{a}
Chemical treatments										
Naphthalene acetic acid - 100ppm (T_1)	8.29	7.95	4.52	2.34	5.78^{defg}	8.35	8.07	4.45	2.42	5.82^{defg}
Naphthalene acetic acid - 200ppm (T_2)	8.26	7.89	4.45	2.35	5.74^{cdef}	8.29	8.02	4.40	2.44	5.79^{cdef}
Gibberellic acid - 150ppm (T_3)	8.21	7.87	4.39	2.30	5.69^{bcde}	8.23	8.00	4.38	2.41	5.76^{bcde}
Gibberellic acid - 300ppm (T_4)	8.01	7.75	4.19	2.27	5.55^{b}	8.09	7.86	4.22	2.49	5.66^{b}
Benzyl adenine - 25ppm (T_5)	8.16	7.83	4.34	2.29	5.65^{bcd}	8.20	7.96	4.31	2.45	5.73^{bcd}
Benzyl adenine - 50ppm (T_6)	8.10	7.79	4.29	2.27	5.61^{bc}	8.15	7.89	4.27	2.46	5.69^{bc}
Control (T_7)	7.89	4.45	2.58	1.15	4.02^{a}	7.96	4.39	2.50	1.23	4.02^{a}
Mean	8.13^{d}	7.36^{c}	4.10^{b}	2.14^{a}		8.18^{d}	7.46^{c}	4.08^{b}	2.27^{a}	
			S.E.±		C.D. (P=0.05)			S.E.±		C.D. (P=0.05)
Maturity stages (MS)			0.026		0.073			0.023		0.064
Chemical treatments (CT)			0.049		0.136			0.043		0.119
Storage period (SP)			0.037		0.103			0.032		0.090
MS × CT			0.069		0.192			0.061		0.168
MS × SP			0.052		0.145			0.046		0.127
CT × SP			0.098		0.271			0.086		0.238
MS × CT × SP			0.139		0.384			0.121		0.336

visibly sound fruits were more in case of mature green stage than that of colour turning stage, wherein the fruits picked at the later stage of maturity were spoiled due to over-ripening and rotting with minimum consumer appeal on all the days of low temperature 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

Table 7: Effect of maturity stages and growth regulators on storage life (days) of guava fruits cv. LUCKNOW-49 at low temperature storage

Chemical treatments	Maturity stages					
	2010			2011		
	Mature green stage (S_1)	Colour turning stage (S_2)	Mean	Mature green stage (S_1)	Colour turning stage (S_2)	Mean
Naphthalene acetic acid - 100ppm (T_1)	22.33	21.00	21.67^{ef}	22.00	20.67	21.33^{ef}
Naphthalene acetic acid - 200ppm (T_2)	22.33	21.33	21.83^{e}	22.33	21.00	21.67^{e}
Gibberellic acid - 150ppm (T_3)	23.00	21.67	22.33^{d}	23.00	21.67	22.33^{d}
Gibberellic acid - 300ppm (T_4)	23.67	22.00	22.83^{bc}	23.67	22.00	22.83^{bc}
Benzyl adenine - 25ppm (T_5)	24.00	22.00	23.00^{b}	24.00	22.33	23.17^{b}
Benzyl adenine - 50ppm (T_6)	24.33	23.00	23.67^{a}	24.67	23.00	23.83^{a}
Control (T_7)	21.00	19.67	20.33^{g}	20.67	20.00	20.33^{g}
Mean	22.95^{a}	21.52^{b}		22.90^{a}	21.52^{b}	
	S.E.±	C.D. (P=0.05)		S.E.±	C.D. (P=0.05)	
Maturity stages (MS)	0.089	0.258		0.089	0.258	
Chemical treatments (CT)	0.167	0.483		0.167	0.483	
MS × CT	0.236	0.683		0.236	0.683	

Table 8 : Effect of maturity stages and growth regulators on organoleptic quality (Overall acceptance) of guava fruits cv. LUCKNOW-49 at low temperature storage

	Storage period (Days)									
	2010					2011				
	5	10	15	20	Mean	5	10	15	20	Mean
Maturity stages										
Mature green stage (S_1)	5.43	6.52	7.33	5.49	6.19^{a}	5.35	6.49	7.27	5.50	6.15^{a}
Colour turning stage (S_2)	6.39	7.56	6.10	4.12	6.04^{b}	6.46	7.57	5.99	4.05	6.02^{b}
Chemical treatments										
Naphthalene acetic acid - 100ppm (T_1)	5.58	6.87	6.79	4.85	6.02^{ef}	5.58	6.87	6.65	4.77	5.96^{f}
Naphthalene acetic acid - 200ppm (T_2)	5.66	6.95	6.87	4.90	6.09^{e}	5.63	6.93	6.74	4.81	6.03^{e}
Gibberellic acid - 150ppm (T_3)	5.77	7.09	6.98	5.03	6.22^{bc}	5.75	7.07	6.87	4.98	6.16^{c}
Gibberellic acid - 300ppm (T_4)	5.76	7.07	6.93	4.98	6.18^{cd}	5.73	7.05	6.83	4.92	6.13^{cd}
Benzyl adenine - 25ppm (T_5)	5.84	7.17	7.05	5.05	6.28^{ab}	5.88	7.13	6.93	5.05	6.25^{ab}
Benzyl adenine - 50ppm (T_6)	5.91	7.21	7.09	5.11	6.33^{a}	5.90	7.19	7.03	5.11	6.31^{a}
Control (T_7)	6.84	6.93	5.27	3.70	5.69^{g}	6.88	6.97	5.36	3.79	5.75^{g}
Mean	5.91^{c}	7.04^{a}	6.71^{b}	4.80^{d}		5.91^{c}	7.03^{a}	6.63^{b}	4.77^{d}	
			S.E.±		C.D. (P=0.05)		S.E.±		C.D. (P=0.05)	
Maturity stages (MS)			0.014		0.040		0.012		0.033	
Chemical treatments (CT)			0.027		0.075		0.023		0.063	
Storage period (SP)			0.020		0.056		0.017		0.047	
MS × CT			0.038		0.106		0.032		0.089	
MS × SP			0.029		0.080		0.024		0.067	
CT × SP			0.054		0.149		0.045		0.125	
MS × CT × SP			0.076		0.211		0.064		0.177	

the advancement of maturity. Mango fruits cv. 'DASHEHARI' harvested immature (85 days after fruit set) were shown to store better with high quality than fruits harvested at more mature stage (90 and 95 days after fruit set) (Kalra and Tandon, 1983). However, Medlicott *et al*. (1990) pointed out that immature fruits of mango stored well at 12^0C but failed to develop full quality characteristics upon ripening at higher temperatures.

Guava fruits treated with growth regulators (NAA, GA_3 and BA) showed an extended storage life or marketable period compared to untreated ones. Among the growth regulators, benzyl adenine irrespective of concentrations studied, significantly increased the storage life of guava fruits closely followed by gibberellic acid (300ppm). However, BA (50ppm) treated mature green guava fruits were the best among all the treatment combinations, having obtained highest storage life of 23.67 and 23.83 days during both the years of investigation. It may be attributed to the fact that BA is a strong and potent anti-oxidant as well as a free radical scavenger, may serve to prevent membrane deterioration by restricting lipid peroxidation and its autocatalytic propagation (Jayachandran, 2000). It has also been reported by Ahmed (1998) in mango, Gouthami (2004) in pomegranate and Alam *et al*. (2010) in papaya, where an increased shelf-life with post harvest application of BA is due to inhibition of alternative respiration and also protection from senescence as a cytokinin. The results are in confirmation with those of Jayachandran (2000), Roy (2006) and Pandey *et al*. (2010) in guava. This may be due to retarded production of ethylene and a higher degree of resistance against pathogens which in turn is being seen as resistance factor in ripening of fruits.

Organoleptic quality :

Organoleptic quality obtained significant differences due to maturity stages, growth regulators, days of storage and their interaction during low temperature storage. With the progress in the storage period, there was an increase in the organoleptic scores for overall acceptance of guava fruits until ripe stage with both treated and untreated ones (Table 8). Visual appearance or look of the fruit is important from the view point of acceptance by the consumer. The fruit appearance and colour improved during ripening with both the maturity stages. The textural quality of a fruit is influenced by skin toughness and flesh firmness. Mature green stage fruits were higher in texture than colour turning stage fruits throughout storage. Brito and Narain (2002) also reported similar decrease in sapota fruit texture during maturation and ripening. Retention of TSS, sugars, acidity and ascorbic acid content of fruits during storage is desirable for the preservation of fruit quality. Taste and flavour of guava is mainly determined by proper brix-acid blend. They were predominantly higher in fruits at colour turning stage during the initial days of storage (5^{th} and 10^{th}) and were rated 'like moderately' to 'like very much', but scored lower than mature green fruits after 10 days of storage. Similar trends were also noticed with fruit flavour and taste during ripening of guava fruits. A rapid decline in these attributes with CT stage fruits after 10 days of low temperature storage could probably be due to over-ripening and rapid senescence. Soares *et al*. (2007) pointed out that esters are the volatile compounds related to the flavour of mature fruits of guava. Sensory scores for fruit appearance and colour, flavour and taste increased until ripe stage, *i.e*. on 10^{th} day and 15^{th} day of storage with CT and MG stages, respectively and then tend to decline till the end of storage. The extended storage life and delay in the climacteric peak of early harvested fruits might be the reason for obtaining highest scores during the later days of storage. On the other hand, fruit texture gradually decreased with the two stages of maturity during ripening. Therefore, the highest scores for overall acceptance were attributed to the fruits harvested at mature green stage (6.19 and 6.15) over colour turning stage (6.04 and 6.02) for a period of 20 days of storage at 10 ± 1^0C.

Post harvest treatment of guava fruits with BA at both the concentrations irrespective of maturity stages studied, recorded the best scores for organoleptic quality which may be attributed to the retarded ripening and softening in BA treated fruits. Control fruits registered highest scores than treated fruits on 5 and 10 days during storage, but the scores were drastically reduced after 10 days as a consequence of over-ripening and rapid senescence resulting in excessive softening, off flavour, poor taste and dull appearance of the fruits. On an average, the treatment control registered poor overall acceptance scores for a period of 20 days and the fruits maintained a score just above 5.5 and were rated as 'Neither like nor dislike'. However, guava fruits treated with BA at both the concentrations scored highest overall acceptance scores on 15^{th} day of storage and were rated

as 'Like moderately' to 'Like very much'. The possible reason for obtaining higher organoleptic scores with BA treatments was attributed to the fact that they obtained higher TSS and sugars, as evidenced by the results. It might also be due high absorption or diffusion of the chemical at higher levels through dipping. Sharma and Dashora (2001) in guava and Bhardwaj *et al*. (2010) in orange also found that BA treated guava fruits scored higher for fruit quality during storage. These results are also in close conformity with those of Sharma *et al*. (2002) and Brahmanchari and Rani (2005) in guava. In the present study, GA_3 -300ppm effectively delayed ripening related changes, but showed poor organoleptic quality till the end of storage period compared to the corresponding lower concentration (GA_3 -150ppm). Moreover, gibberellic acid has been proved to increase storage life and maintain fruit quality to a maximum extent when applied before harvest (pre-harvest spray) compared to post-harvest applications. Though NAA has been reported to improve storage life of guava (Singh, 1988 and Jagadeesh and Rokhade, 1998) and many fruits (Gautam *et al*., 2003 in mango and Sudha *et al.*, 2007 in sapota) in the present study, it failed to exert any significant influence over control. However, explaining the discrepancies among the results from various studies is rather difficult.

Conclusion :

The stage of maturity or ripeness at harvest had a significant effect on extending storage life and quality of guava. Further, it could be concluded that freshly harvested mature green (MG) guava fruits treated with Benzyl adenine (50 ppm) showed promising result in delaying physiological and biochemical changes during cold storage (10±1^{0}C and 90±5% RH).

Acknowledgement:

Thanks to the staff of Quality Control Laboratory, A.N.G.R.A.U., Rajendranagar, Hyderabad for scientific advice and technical support during the conduct of this research work.

LITERATURE CITED

Ahmed, M.N. (1998). Studies on the effect of post harvest application of polyamines and antioxidants on the shelf-life of mango cv. Baneshan. M.Sc. Thesis, Acharya N.G. Ranga Agricultural University, Hyderabad, A.P. (INDIA).

Alam, M.S., Hussain, M.M., Ara, M.I., Amanullah, A.S.M. and Mondal, M.F. (2010). Effects of packaging materials and growth regulators on quality and shelf-life of papaya. *Bangladesh Res. Publ. J.*, **3** (3) : 1052-1061.

Amerine, M.A., Pangborn, R.M. and Roessler, E.B. (1965). Laboratory studies: Quantity-Quality evaluation. In: *Principles of Sensory Evaluation*, Academic Press, NY. pp.367-375.

Asrey, R., Patel, V.B., Singh, S.K. and Sagar, V.K. (2008). Factors affecting fruit maturity and maturity standards - A review. *J. Food Sci. Technol*., **45** (5) :381-390.

Awad, M. and Young, R.E. (1980). Avocado pectinmethy lesterase activity in relation to temperature, ethylene and ripening. *J. Amer. Soc. Hort. Sci*., **105** (5) : 638-641.

Azzolini, M., Pedro, A.J. and Spot, M.H.F. (2004). Maturation stage and post harvest quality of 'Pedro Sato' guavas. *Revista Brasileria de Fruitcultura*, **26**(1):29-31.

Barua, P.C., Deka, B.C. and Buragohain, J. (2010). Post-harvest treatments to improve the shelf-life of tomato fruits at ambient conditions. *Indian J. Hort*., **67**(2):249-254.

Basulto, F.S., Duch, E.S., Gil, F.E., Plaza, R.D., Saavedra, A.L. and Santamaria, J.M. (2009). Postharvest ripening and maturity indices for maradol papaya. *Interciencia*, **34** (8) : 583-588.

Bhardwaj, R.L., Dashora, L.K. and Mukerjee, S. (2010). Effect of neem leaf extract and benzyladenine on post harvest shelf-life of orange (*Citrus reticulata* Blanco). *J. Adv. Dev. Res*., **1**(1) : 32-37.

Bhardwaj, R.L., Meena, R.R. and Mukerjee, S. (2005). Role of plant growth regulators in guava (*Psidium guajava* L.) a review. *Agric. Rev*., **26** (4) : 281-287.

Boora, R.S. (2012). Improvement in guava (*Psidium guajava* L.) – A review. *Agric. Rev*., **33** (4) : 341-349.

Brahmanchari, V.S. and Rani, R. (2005). Shelf-life extension in guava with pre-harvest sprays of certain growth substances and polyethylene wrapping. *Haryana J. Hort. Sci*., **34** (1-2) : 36-38.

Brito, E.S. and Narain, N. (2002). Physical and chemical characteristics of sapota fruit at different stages of maturation. *Pesquisa Agropecuária Brasileira*, **37** (4): 567 - 572.

Bron, I.U. and Jacomino, A.P. (2006). Ripening and quality of 'Golden' papaya fruit harvest at different maturity stages. *Brazilian J. Plant Physiol*., **18** (3) : 389-396.

Bron, I.U., Ribeiro, R.V., Cavalini, F.C., Jacomino, A.P. and Trevisan, M.J. (2005). Temperature related changes in

respiration and Q_{10} coefficient of guava. *Scientia Agricola*., **62** (5) : 458-463.

Dashora, L. (2001). Influence of pre and post-harvest application of plant growth regulators on the physico-chemical changes and shelf-life of guava fruits (*Psidium guajava* L.) cv. LUCKNOW-49. Ph.D. Thesis, Maharana Pratap University of Agriculture and Technology, Udaipur, RAJASTHAN (INDIA).

Desai, B.B., Sangale, P.B. and Despande, P.B. (1984). Hormonal regulation of hydrolytic and oxidative enzymes during ripening of three cultivars of banana. *J. Maharastra Agric. Univ*., **9** (1) : 24-26.

Dhillon, K.S., Singh, S.N. and Gill, S.S. (1987). Developmental physiology of guava I. Physical characters. *Punjab Hort. J*., **27**:28-33.

Dhoot, L.R., Desai, U.T. and Rane, D.A. (1984). Studies on the shelf-life of guava fruits with polythene packaging and chemical treatments. *J. Maharastra Agric. Univ.*, **9** (21): 185-188.

Elgar, H.J., Watkins, C.B. and Lalu, N. (1999). Harvest date and crop load effects on a carbon dioxide related storage injury of Braeburn apple. *Hort Sci*., **34** (20) : 305-309.

Gautam, B., Sarkar, S.K. and Reddy, Y.N. (2003). Effect on post harvest treatments on shelf-life and quality of Banganapalli mango. *Indian J. Hort*., **60** (2) : 135-139.

Gautam, S.K. and Chundawat, B.S. (1989). Post harvest changes in sapota cv. KALIPATTI. Effect of various post harvest treatments on biochemical changes. *Indian J. Hort*., **46** : 310-315.

Gonge, A.P., Patel, N.L., Ahlawat, T.R. and Patil, S.J. (2014). Influence of harvesting maturity and low temperature storage on shelf-life and physico-chemical quality of banana cv. GRAND NAINE. *Indian J. Hort*., **71** (3) : 441-445.

Gouthami, N. (2004). Studies on browning and discoloration of arils of pomegranate (*Punica granatum* L.) Ph.D. Thesis, Acharya N.G. Ranga Agricultural University, Hyderabad, A.P. (INDIA).

Hansen, E. (1966). Postharvest physiology of fruit. *Annu. Rev. Plant Physiol*., **17** : 459-480.

Hiwale, S.S. and Singh, S.P. (2003). Prolonging shelf-life of guava (*Psidium guajava* L.). *Indian J. Hort*., **60** (1):1-9.

Jagadeesh, S.L. and Rokhade, A.K. (1998). Effect of post harvest treatments on keeping quality of guava (*Psidium guajava* L.) fruits cv. SARDAR-1. *Karnataka J. Agric. Sci*., **11** (4): 1003 - 1008.

Jain, N., Dhawan, K., Malhotra, S.P., Siddiqui, S. and Singh, R. (2001). Compositional and enzymatic changes in guava (*Psidium guajava* L.) fruits during ripening. *Acta Physiol. Plant*., **23** (3) : 357-362.

Jain, S.K. and Mukherjee, S. (2011). Enhancing keeping quality of fruits in mango cv. Langra. *Indian J. Hort.*, **68** (1) : 142-144.

Jayachandran, K.S. (2000). Studies on effect of pre and post-harvest treatments with growth regulators, chemicals and storage temperatures on shelf-life of guava (*Psidium guajava* L.) cv. LUCKNOW-49 fruits. M.Sc. Thesis, Acharya N.G. Ranga Agricultural University, Hyderabad, A.P. (INDIA).

Jayachandran, K.S., Srihari, D. and Reddy, Y.N. (2007). Post-harvest application of selected antioxidants to improve the shelf-life of guava fruit. *Acta Hort*., **735**:627-632.

Johnston, J.W., Hewett, E.W., Hertog, M.L.A.T.M. and Harker, P.R. (2002). Harvest date and fruit size affect postharvest softening of apple fruit. *J. Hort. Sci. Biotech.*, **77** (3) : 355-360.

Kader, A.A. (1999). Guava-produce facts. In: *Perishables Handling*. Quarterly, University of California, Davis. pp.19-20.

Kalra, S.K. and Tandon, D.K. (1983). Ripening behaviour of 'Dashehari' mango in relation to harvest period. *Scientia Hort*., **19** : 263-269.

Killadi, B., Singh, M.D., Singh, B.P. and Singh, R.A. (2007). Shelf-life evaluation of guava (*Psidium guajava* L.) cultivars. *Acta Hort*., **735** : 603-607.

Krishnamurthy, S. and Subramanyam, H. (1970). Respiratory climacteric and chemical changes in the mango fruit (*Mangifera indica* L.). *J. Amer. Soc. Hort. Sci*., **95**(3):333-337.

Kudachikar, V.B., Kulkarni, S.G., Prakash, K.M.N., Vasantha, M.S., Prasad, A.B. and Ramana, K.V.R. (2001). Physico-chemical changes during maturity of mango variety Neelum. *J. Food Sci. Technol*., **38** : 540-545.

Lalel, H.J.D., Singh, Z. and Tan, S.C. (2003). Maturity stage at harvest affects fruit ripening, quality and biosynthesis of aroma volatile compounds in 'Kensington Pride' mango. *J. Hort. Sci. Biotech.*, **78** (2) : 225-233.

Lieberman, M., Baker, J.E. and Sloger, M. (1977). Influence of plant hormones on ethylene production in apple, tomato and avocado slices during maturation and senescence. *Plant Physiol.*, **60**:214-217.

MacRae, E.A., Lallu, N., Searle, A.N. and Bowen, J.H. (1989). Changes in the softening and composition of kiwifruit

(*Actinidia deliciosa*) affected by maturity at postharvest treatments. *J. Sci. Food Agric*., **49**:413-430.

Mapson, L.W. (1970). Vitamins in fruits. pp.376-377. In: *Biochemistry of fruits and their products*, chapter XII, Vol. **I**, Hulme AC (Ed.). Academic Press, London, UNITED KINGDOM.

Mattoo, A.K., Murata, T., Pantastico, E.B., Chachin, K., Ogata, K. and Phan, C.T. (1975). Chemical changes during ripening and senescence. In: *Post harvest physiology, handling and utilization of tropical and subtropical fruits and vegetables*. Pantastico EB (Ed.) AVI Westport. pp.103-127.

McGuire, R.G. (1992). Reporting of objective colour measurements. *Hort Sci*., **27**:1254-1255.

Meena, R.R., Mukerjee, S.K. and Singh, D. (2008). Effect of pre and post-harvest applications of plant growth regulators and chemicals on the acidity and sugar changes in guava (*Psidium guajava* L.) cv. LUCKNOW-49. *Environ. Ecol*., **26** (4B) : 2140-2144.

Medlicott, A.P., Sigrist, J.M.M. and Sy, O. (1990). Ripening of mangoes following low temperature storage. *J. Amer. Soc. Hort. Sci*., **115** (3) : 430-434.

Mercado-Silva, E., Benito-Bautista, P. and Garcia-Velasco, M.A. (1998). Fruit development, harvest index and ripening changes of guavas produced in central Mexico. *Postharvest Biol. Technol*., **13**:143-150.

Mitra, S.K., Devi, H.L., Chakraborty, I. and Pathak, P.K. (2012). Recent development in post harvest physiology and storage of guava. *Acta Hort*., **959**:89-95.

Mitra, S.K.,Gurung, M.R. and Pathak, P.K. (2008). Guava production and improvement in India: An overview. *Acta Hort*., **787** : 59-65.

Mondal, K., Malhotra, S.P., Jain, V. and Singh, R. (2009). Partial purification and characterization of pectin methylesterase from ripening guava (*Psidium guajava* L.) fruits. *Acta Physiol. Plant*., **31**: 81-87.

Mondal, K., Singh, A.P., Saxena, N., Malhotra, S.P. and Dhawan, K. (2008). Possible interactions of polyamines and ethylene during ripening of guava (*Psidium guajava* L.) fruits. *J. Food Biochem*., **32**:46-59.

Narayana, C.K. and Mustaffa, M.M. (2007). Influence of maturity on shelf-life and quality changes in Banana during storage under ambient conditions. *Indian J. Hort*., **64** (1):12-16.

Pal, D.K. and Selvaraj, Y. (1979). Changes in pectin and pectin esterase activity in developing guava fruits. *J. Food Sci. Technol*., **16**:115-116.

Pandey, S.K., Joshua, J.E., Bisen and Abhay (2010). Influence of gamma irradiation growth retardants and coatings on the shelf-life of winter guava fruits (*Psidium guajava* L.). *J. Food Sci. Technol*., **47** (1) : 124-127.

Panse, V.G. and Sukhatme, P.V. (1985). *Statistical methods for agricultural workers*. Indian Council for Agricultural Research (ICAR), NEW DELHI, INDIA.

Pantastico, E.R., Chatopadhyay, T.K. and Subramanayam, H. (1975). Storage and commercial storage operations. In: *Post harvest physiology, handling and utilization of tropical and subtropical fruits and vegetables*. Pantastico EB (Ed.) AVI Westport. pp.314-338.

Patel, A.B., Patel, B.I. and Katrodia, J.S. (1993). Extension of storage life of guava (*Psidium guajava* L.) fruits. *Indian Food Packer*, **36** (1) : 5-10.

Patel, R.K., Maiti, C.S., Deka, B.C., Deshmukh, N.A., Verma, V.K. and Nath, A. (2015). Physical and biochemical changes in guava (*Psidium guajava* L.) during various stages of fruit growth and development. *Internat. J. Agric. Environ. Biotech*., **8** (1) :75-82.

Paull, R.E. and Goo, T. (1983). Relationship of guava (*Psidium guajava* L.) fruit detachment force to the stage of fruit development and chemical composition. *Hort Sci*., **18** (1) : 65-67.

Pila, N., Gol, N.B. and Rao, T.V.R. (2010). Effect of post harvest treatment on physicochemical characteristics and shelf-life of tomato (*Lycopersicon esculentum* Mill.) fruits during storage. *American-Eurasian J. Agric. Environ. Sci*., **9** (5) : 470-479.

Pool, R.M., Weaver, R.J. and Klliewer, W.M. (1972). The effect of growth regulators on changes in fruits Thomson seedless during cold storage. *J. Amer. Soc. Hort. Sci.*, **97** : 67-70.

Pradeep, V., Mahendran, R. and Alagusundaram, K. (2014). Classification of guava based on colour using computer vision system. *Trends Biosciences*, **7**(16): 2168-2174.

Rajput, C.B.S., Singh, S.P. and Ram, B.P. (1992). Effect of gibberellic acid, ferrous sulphate and ascorbic acid on the shelf-life on guava (*Psidium guajava* L.) fruits cv. ALLAHABAD SAFEDA. *Prog. Hort*., **24** (3-4) : 128-134.

Ramchandra (1995). Biochemical changes during maturity and storage in guava fruits. *Indian J. Hill Farm.*, **8** (1) :116-21.

Randhawa, J.S., Dhillon, B.S., Bal, J.S. and Bhullar, J.S. (1987). Studies on the pectin methylesterase activity during cold storage of 'Patharnakh' pear. *J. Food Sci. Tech*., **24**: 71-73.

Ranganna, S. (1986). *Handbook of analysis and quality control for fruit and vegetable products*. II[nd] Ed., Tata Mac Graw Hill Publication Co. Ltd., NEW DELHI, INDIA.

Roy, A. (2006). Effect of post harvest treatments on shelf-life and quality of guava (*Psidium guajava* L.) cv. L-49. M.Sc. Thesis, Acharya N.G. Ranga Agricultural University, Hyderabad, A.P. (INDIA).

Sacher, J.A. (1973). Senescence and Post-harvest physiology. *Annu. Rev. Plant Physiol*., **24**:197-224.

Sadasivam, S. and Manickam, A. (1992). *Biochemical methods.* New Age International Publishers, NEW DELHI, INDIA.

Saha, A.K. (1971). Effect of post harvest treatment with growth regulators on the ripening and chemical composition of guava (*Psidium guajava* L.) fruits. *Indian J. Hort*., **28**:11-15.

Sakhale, B.K., Pawar, V.N. and Kapse, B.M. (2009). Studies on the extension of shelf-life of 'Kesar' Mango (*Mangifera indica* L.). *Acta Hort*., **820** : 643-651.

Saxena, M. and Gandhi, C.P. (2014). *Indian Horticulture Database 2014*, National Horticulture Board (NHB), Gurgaon. Department of Agriculture & Cooperation, Govt. of India. pp.76-83.

Selvaraj, Y., Pal, D.K., Raja, M.E. and Rawal, R.D. (1998). Biochemistry of guava (*Psidium guajava* L.) fruit ripening: Changes in respiration rate, ethylene production and enzyme activity. *Indian J. Hort*., **35** (1):1- 9.

Soares, F.D., Pereira, T., Marques, M.O.M. and Monteiro, A.R. (2007). Volatile and non-volatile chemical composition of the white guava fruit (*Psidium guajava* L.) at different stages of maturity. *Food Chem*., **100**:15-21.

■ WEBLIOGRAPHY

Paull, R.E. and Chen, C.C. (2002). Guava postharvest technology research and information centre. *http:// postharvest. ucdavis.edu/Produce/ProduceFacts/ Fruitguava _graphics.shtml.*