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Full Length Research Article

Effect of Maturity Stage on Physico-Chemical Changes of Guava (*Psidium guajava* L.) Cultivars under Ambient Condition

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Abstract

Guava (*Psidium guajava* L.) is a perennial fruit crop that grows in tropical and subtropical regions of the world and is most widely grown in India. It is indigenous to tropical America and belongs to the family Myrtaceae. Guava is well known for its nutritional value, being an excellent source of vitamin C and pectin, and having great economic value. Guava fruits show a typical increase in respiration and ethylene production during ripening because they are climacteric. The production of guavas for the fresh market is typically restricted to a few days due to their high perishability. The experiment's findings demonstrated that guavas' level of maturity or ripeness at harvest had significant effects on both their quality and storage life. The mature green stage of the fruit showed promising results in delaying the physico-chemical changes when compared to the colour turning stage and ripe stage of development. Considering all the parameters, Lalit and Allahabad Safeda cultivars of guava were identified as the best cultivars in terms of better post-harvest life, while Lalit excelled in terms of maximum total carotenoids content, total antioxidant content, and total chlorophyll content. The weight loss and decay loss were minimal observed in Allahabad Safeda cultivars.

***Key words*:** *Psidium guajava* L., Maturity, Post-harvest quality, Shelf life, Storage

One of the most well-known edible fruits is the guava (*Psidium guajava* L.), which is produced extensively in over sixty countries throughout the tropical and subtropical zones of the world. The fruits are delicious and abundant in pectin, calcium, phosphorus, iron, and vitamin C. According to Patra *et al.* [1], guava fruits can be consumed fresh or used to make jam, jelly, nectar, paste, etc. Furthermore, the guava fruit's high pectin content may be significant in reducing cholesterol and decreasing the risk of cardiovascular disease. In terms of market accessibility and affordability for the underprivileged, the guava, often referred to as the "poor man's apple," truly is the fruit for the masses [2]. There are three distinct fruiting seasons; rainy (Ambe bahar), winter (Mrig bahar), and spring (Hasta bahar). It is desirable to take only one crop per year. In South India, despite its poor quality, the rainy season crop is chosen because of its high price. In North India, the quality of the winter crop is higher, and the fruits also escape white flies' attack. Therefore, it is necessary to standardise the external traits, physical traits, and chemical composition of commercially significant guava cultivars.

It is well recognised that different physiological and biological changes take place throughout fruit growth and development. Maturity affects the quality and storage life of fruits [3]. Fruit quality is greatly influenced by harvesting at the proper stage of maturity. In India, there is a lack of knowledge regarding the physical and biochemical changes in guava during various stages of fruit development and maturity. Such details are necessary because the physico-chemical changes that occur throughout fruit maturation can serve as key criteria for identifying the ideal time for fruit harvesting for improved quality and a longer shelf life. In accordance with these facts, a comprehensive analysis of the physical and biochemical changes that occur at various stages of maturity was conducted in order to determine the proper maturity standards and ensure that fruits are harvested at the ideal time for better quality and a desired shelf life. Because of the guava's high commercial and nutritional value, it is regarded as being superior to many other fruits [4]. Different guava cultivars are categorised according to the colour, shape, and size of the fruit. One of the main indicators of guava maturity is the colour of the skin, which changes from dark green during the immature stage to yellow when fully ripened. Guavas have a limited shelf life and ripen very quickly after being harvested, which makes them climacteric fruits. Fruit should be mature, full-sized, and firm in texture if it is going to be delivered to distant markets, but it shouldn't have a clear colour break on the surface. Fruits for the local market may be gathered when they are more advanced in their maturation [5]. To maintain the post-harvest quality of guava fruits, however, they must be harvested at the proper stage of maturity [6-7].

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MATERIALS AND METHODS

Uniform medium-sized guava fruits of cultivars Lalit, Allahabad Safeda, and Shweta were harvested at mature green, colour break, and ripe stages respectively, from Raghuvanshi Farm, Cholapur, Varanasi, Uttar Pradesh. Fruits were transported in CFB boxes with minimal delay after harvest and brought to the postharvest laboratory. All the dirt and other extraneous material from the fruits were removed. The fruits were washed with tap water and allowed to dry. After discarding the diseased, spotted, and bruised fruits, they were then disinfected with a 2% sodium hypochlorite solution for 2 minutes. After that, the fruits were placed into different groups and placed in the open conditions of the postharvest laboratory, and then some important initial physico-chemical observations were recorded by analysing the fruits. The experiment was laid out in a factorial completely randomized design with three replicates for each treatment at a 3-day interval during storage under ambient conditions having 21 ± 3°C and 75 ± 5% RH. The influence of maturity stage on physico-chemical attributes such as weight loss, specific gravity, pH, total chlorophyll content, total carotenoids content, malondialdehyde content, total antioxidant capacity, and decay loss of guava fruits was recorded during storage at ambient conditions. The physiological loss in weight (PLW) of fruit was calculated as the loss of weight in grammes to the initial weight and expressed in percentage. The specific gravity of fruit was recorded using a wide-mouth cylinder filled to the brim with water. Fruit was immersed in the cylinder, and the run-off collected was measured, which gave the volume of fruit. Specific gravity was calculated by dividing the weight of fruit (g) by the volume of displaced water (ml). Pulp tissues (20 g) were homogenized and filtered, and the pH value of the filtered juice was determined with a digital pH metre (Model MPM-20, Make Metred). The quantitative estimation of total chlorophyll content was carried out by the method of Arnon [8], while carotenoids were determined by Duxbury and Yentsch [9]. The malondialdehyde content in guava fruit during storage was estimated according to the method of Zheng and Tian [10]. Total antioxidant capacity was determined using the CUPRAC assay (Cupric Reducing Antioxidant Capacity) by Apak *et al.* [11]. Decay loss was assessed on the basis of the appearance of symptoms of fungal growth or rotting, irrespective of the severity. The results were expressed in percentages (%). The data from the experiment with respect to various parameters during storage were subjected to analysis of variance (ANOVA), with treatments and storage duration as sources of variation. The significance of the difference between the means was determined by HSD Tukey's test ($p \leq 0.05$) using IBM SPSS Statistics 26.

RESULTS AND DISCUSSION

The present investigation's findings, as well as relevant discussions, have been presented under the following headings:

Weight loss (%)

Physiological loss in weight (PLW) is one of the most important characteristics that determine the post- harvest quality of fruits, and any loss in weight of fruits is likely to decline the quality of product. The weight loss in fresh fruits is largely due to water loss caused by transpiration and respiration processes. The gradient in water pressure between the fruit tissue and the surrounding atmosphere, as well as the temperature of storage, both affect the rate of water loss. Results revealed that the weight loss of guava fruits increased with the prolonging of storage period. It was observed that physiological weight loss was significantly affected by the cultivars, days after storage and also their interaction. There was a significant difference in weight loss among various maturity stages in all the cultivars up to 12 days of storage. Increase in weight loss was observed with the advancement of maturity stage minimum from mature green stage to ripe stage fruits. After 3 days of storage, among the cultivars, Allahabad Safeda showed the minimum weight loss (4.78, 5.76 and 7.54%), followed by Shweta (6.97, 7.95 and 9.73%), whereas it was maximum in cultivar Lalit (7.36, 8.82 and 11.55%) at mature green, colour break and ripe stages, respectively. However, after 12 days of storage, lowest value of weight loss was recorded in cultivar Allahabad Safeda (18.57, 21.74 and 24.93%), followed by Shweta (22.29, 26.49 and 29.25%), whereas the highest value of weight loss was recorded at Lalit (26.21, 32.34 and 35.06%) at mature green, colour break and ripe stages, respectively. Chandra [12] also noticed that physiological loss in weight reached a maximum at day 12 of storage. These results are in agreement with those of Hedge and Chharia [13]. The differences in weight loss could be due to differences in the water vapour permeability of the varieties. Cultivar differences in the weight loss of red raspberry during storage have been reported earlier [14].

Table 1 Effect of maturity stage on weight loss (%) of guava cultivars during storage at ambient condition

Maturity stages		Weight loss (%)				
		Days after storage (DAS)				
		0 DAS	3 DAS	6 DAS	9 DAS	12 DAS
Lalit	Mature green stage	0	7.36 ± 0.53 b	15.38 ± 0.48 b	20.97 ± 0.45 b	26.21 ± 0.35 b
	Colour break stage	0	8.82 ± 0.26 a	17.65 ± 0.56 a	26.13 ± 0.74 a	32.34 ± 1.43 ab
	Ripe stage	0	11.55 ± 0.33 a	18.44 ± 0.52 a	27.12 ± 0.83 a	35.06 ± 1.99 a
Allahabad	Mature green stage	0	4.78 ± 0.37 b	10.23 ± 0.76 b	13.69 ± 0.44 c	18.57 ± 0.64 c
Safeda	Colour break stage	0	5.76 ± 0.69 ab	11.77 ± 0.46 b	17.86 ± 0.46 b	21.74 ± 1.09 b
	Ripe stage	0	7.54 ± 1.08 a	13.97 ± 0.71 a	19.51 ± 0.73 a	24.93 ± 0.72 a
Shweta	Mature green stage	0	6.97 ± 0.39 b	11.86 ± 0.43 b	18.13 ± 0.26 c	22.29 ± 0.36 c
	Colour break stage	0	7.95 ± 0.15 ab	15.09 ± 0.29 a	21.42 ± 0.35 b	26.49 ± 0.45 b
	Ripe stage	0	9.73 ± 0.64 a	16.82 ± 0.54 a	23.51 ± 0.52 a	29.25 ± 0.81 a

Specific gravity

An indicator of fruit maturity is specific gravity. Fruits' internal characteristics, such as dry matter, soluble solids, or physical disorders, have been shown to be correlated with their specific gravity. Results showed that as storage time increased, the specific gravity of guava fruits decreased. Significant variation in specific gravity was not observed between different maturity stages in all the cultivars up to the end of storage. However, 3 days onwards, among the cultivars, Allahabad Safeda exhibited maximum specific gravity (1.07, 1.06 and 1.05), followed by Lalit (1.06, 1.04 and 1.02), whereas it was minimum in cultivar Shweta (1.03, 1.02 and 1.01) at mature

green, colour break and ripe stages, respectively. Likewise, after 12 days of storage, the highest value of specific gravity was recorded in cultivar Allahabad Safeda (1.02, 1.01 and 1.00), followed by Lalit (1.01, 1.00 and 0.98), while lowest value of specific gravity was recorded at Shweta (1.00, 0.99 and 0.98) at mature green, colour break and ripe stages, respectively. The specific gravity significantly influenced storage periods. The decrease in the specific gravity was due to the decrease in weight and volume of fruits because of the conversion of starch into sugar. The results of this investigation were somewhat similar to previous report of [15].

Table 2 Effect of maturity stage on specific gravity of guava cultivars during storage at ambient condition

Maturity stages		Specific gravity				
		Days after storage (DAS)				
		0 DAS	3 DAS	6 DAS	9 DAS	12 DAS
Lalit	Mature green stage	1.07 ± 0.011 a	1.06 ± 0.016 a	1.04 ± 0.011 a	1.03 ± 0.012 a	1.01 ± 0.014 a
	Colour break stage	1.06 ± 0.006 a	1.05 ± 0.006 a	1.03 ± 0.008 ab	1.02 ± 0.003 a	1.00 ± 0.004 a
	Ripe stage	1.03 ± 0.001 b	1.02 ± 0.001 b	1.02 ± 0.007 b	1.01 ± 0.010 a	0.98 ± 0.038 a
Allahabad	Mature green stage	1.09 ± 0.015 a	1.07 ± 0.010 a	1.05 ± 0.010 a	1.04 ± 0.015 a	1.02 ± 0.010 a
Safeda	Colour break stage	1.07 ± 0.010 ab	1.06 ± 0.015 a	1.04 ± 0.012 a	1.03 ± 0.010 a	1.01 ± 0.005 a
	Ripe stage	1.06 ± 0.011 c	1.05 ± 0.010 a	1.03 ± 0.006 a	1.01 ± 0.017 a	1.00 ± 0.001 a
Shweta	Mature green stage	1.04 ± 0.012 a	1.03 ± 0.013 a	1.02 ± 0.008 a	1.01 ± 0.005 a	1.00 ± 0.002 a
	Colour break stage	1.03 ± 0.015 a	1.02 ± 0.005 a	1.01 ± 0.003 a	1.00 ± 0.003 a	0.99 ± 0.010 a
	Ripe stage	1.02 ± 0.010 a	1.01 ± 0.003 a	1.00 ± 0.006 a	0.98 ± 0.004 a	0.96 ± 0.003 a

Values are mean ± standard error of three replicate determinations (n=3). According to HSD Tukey's test, values in the same column with different letters are significantly different ($p < 0.05$)

Table 3 Effect of maturity stage on pH of guava cultivars during storage at ambient condition

Maturity stages		pH				
		Days after storage (DAS)				
		0 DAS	3 DAS	6 DAS	9 DAS	12 DAS
Lalit	Mature green stage	5.01 ± 0.09 b	5.06 ± 0.14 a	5.15 ± 0.17 a	5.27 ± 0.18 a	5.40 ± 0.17 a
	Colour break stage	5.18 ± 0.03 ab	5.23 ± 0.05 a	5.30 ± 0.07 a	5.40 ± 0.08 a	5.56 ± 0.08 a
	Ripe stage	5.35 ± 0.04 a	5.41 ± 0.05 a	5.47 ± 0.06 a	5.54 ± 0.07 a	5.63 ± 0.05 a
Allahabad	Mature green stage	4.74 ± 0.04 c	4.88 ± 0.06 c	5.02 ± 0.05 c	5.14 ± 0.12 b	5.24 ± 0.03 b
Safeda	Colour break stage	4.95 ± 0.03 b	5.06 ± 0.02 b	5.16 ± 0.02 b	5.25 ± 0.02 b	5.31 ± 0.04 b
	Ripe stage	5.09 ± 0.02 a	5.17 ± 0.03 a	5.26 ± 0.03 a	5.36 ± 0.04 a	5.43 ± 0.03 a
Shweta	Mature green stage	4.85 ± 0.02 b	5.02 ± 0.06 b	5.11 ± 0.09 c	5.21 ± 0.07 c	5.28 ± 0.01 c
	Colour break stage	5.04 ± 0.01 a	5.16 ± 0.08 a	5.24 ± 0.03 b	5.33 ± 0.03 b	5.42 ± 0.05 b
	Ripe stage	5.13 ± 0.03 a	5.22 ± 0.05 a	5.32 ± 0.14 a	5.41 ± 0.08 a	5.49 ± 0.02 a

pH

The study revealed that pH progressively and significantly increased with the storage time up to 12th day. The increase in pH during the shelf-life study could be the result of enzymatic activities and the senescence of the fruit, which eventually ended up in reduction of acid level. It could also be affected by cultivars, ripening levels, storage conditions, and microbial contamination. After 3 days of storage, among various cultivars, Lalit showed maximum pH (5.06, 5.23 and 5.41), followed by Shweta (5.02, 5.16 and 5.22), while the minimum pH was observed in Allahabad Safeda (4.88, 5.06 and 5.17) at mature green, colour break and ripe stages, respectively. However, after 12 days of storage, the highest value of pH was recorded in cultivar Lalit (5.40, 5.56 and 5.63), followed by Shweta (5.28, 5.42 and 5.49), whereas lowest value was recorded in Allahabad Safeda (5.40, 5.56 and 5.63) at mature green, colour break and ripe stages, respectively. Among different maturity stages, the maximum pH was noted at ripe stage, followed by colour break stage and the minimum pH was found at mature green stage [16-17].

Table 4 Effect of maturity stage on total chlorophyll content (mg/100 g FW) of guava cultivars during storage at ambient condition

Maturity stages		Total Chlorophyll content (mg/100 g FW)				
		Days after storage (DAS)				
		0 DAS	3 DAS	6 DAS	9 DAS	12 DAS
Lalit	Mature green stage	7.97 ± 0.55 a	7.06 ± 0.49 a	5.64 ± 0.43 a	4.15 ± 0.38 a	2.56 ± 0.30 a
	Colour break stage	7.04 ± 0.42 b	6.08 ± 0.52 b	4.73 ± 0.30 b	3.63 ± 0.27 a	1.72 ± 0.26 ab
	Ripe stage	4.95 ± 0.46 c	4.14 ± 0.32 b	3.16 ± 0.26 c	2.13 ± 0.28 b	1.21 ± 0.17 b
Allahabad	Mature green stage	6.90 ± 0.32 a	5.38 ± 0.52 a	4.16 ± 0.21 a	3.24 ± 0.09 a	2.41 ± 0.16 a
Safeda	Colour break stage	5.50 ± 0.54 b	4.65 ± 0.75 ab	3.62 ± 0.55 b	2.78 ± 0.17 ab	1.95 ± 0.46 b
	Ripe stage	4.48 ± 0.15 c	3.58 ± 0.81 b	3.09 ± 0.24 b	2.17 ± 0.26 b	1.10 ± 0.31 c
Shweta	Mature green stage	6.26 ± 0.78 a	5.19 ± 0.19 a	4.03 ± 0.11 a	3.02 ± 0.15 a	2.18 ± 0.27 a
	Colour break stage	5.20 ± 0.27 b	4.47 ± 0.10 ab	3.58 ± 0.42 b	2.79 ± 0.08 a	1.77 ± 0.11 b
	Ripe stage	4.15 ± 0.18 c	3.38 ± 0.24 b	2.64 ± 0.28 b	1.73 ± 0.34 b	0.95 ± 0.12 c

Values are mean ± standard error of three replicate determinations (n=3). According to HSD Tukey's test, values in the same column with different letters are significantly different ($p < 0.05$)

Total chlorophyll content (mg/100 g FW)

A significant difference in total chlorophyll content was recorded between various maturity stages and all the cultivars during storage. Skin colour of guava is an important criteria for determining the marketability of fruits, as most of the consumers select the fruit on the basis of skin colour. The skin colour of guava fruits changes from green to yellow during ripening [18]. In contrast, the chlorophyll content decreases during storage, and this decrease was strongly influenced by the storage time. After 3 days of storage, among various cultivars, cultivar Lalit recorded maximum total chlorophyll content (7.06, 6.08 and 4.14 mg/100 g FW), followed by Allahabad Safeda (5.38, 4.65 and 3.58 mg/100 g FW), whereas it was minimum in cultivar Shweta (5.19, 4.47 and 3.38 mg/100 g FW) at mature green, colour break and ripe stages, respectively. Likewise, after 12 days of storage, the highest value of total chlorophyll content was noted in cultivar Lalit (2.56, 1.72 and 1.21 mg/100 g FW), followed by Allahabad Safeda (2.41, 1.95 and 1.10 mg/100 g FW), whereas lowest value was recorded in Shweta (2.18, 1.77 and 0.95 mg/100 g FW) at mature green, colour break and ripe stages, respectively. Among different maturity stages, the maximum chlorophyll content was observed at mature green stage, followed by colour break stage, whereas the, minimum chlorophyll content was recorded at ripe stage after 3 days storage onwards and similar trend maintained up to the end of storage period. The loss of green surface colour could be related to the ethylene-triggered natural ripening process that occurs as a result of the breakdown of chlorophyll molecules in parallel with an increase in carotenoids content [19]. Loss of chlorophyll during storage period is related to the conversion of chloroplasts into chromoplasts, which contain yellow and red carotenoids pigment. The changes in chlorophyll are probably due to the differential activity of chlorophyll degrading enzymes like chlorophyllase, chlorophyll oxidase and peroxidase throughout ripening period. Increased activity of chlorophyllase enzyme is responsible for major loss of chlorophyll during ripening. Chlorophyll pigment is responsible for green colour which degrades with the onset of ripening and changes to pheophytin and pheophorbide [20].

Total carotenoids content (mg/100 g FW)

In this study, it was found that as the storage period progressed, the amount of total carotenoids in guava fruits significantly increased. There was a significant difference in total carotenoids content among mature green and ripe stage fruits, respectively in all the cultivars. However, during initial days and onwards, among the different maturity stages, the maximum total carotenoids content was exhibited at ripe stage, followed by colour break stage and the minimum total carotenoids content was recorded at mature green stage. After 3 days of storage, among the cultivars, Lalit showed maximum total carotenoids content (65.63, 73.89 and 96.24 mg/100 g FW), followed by Allahabad Safeda (43.71, 51.26 and 60.57 mg/100 g FW), whereas it was minimum in cultivar Shweta (35.87, 47.13 and 55.68 mg/100 g FW) at mature green, colour break and ripe stages, respectively. However, after 12 days of storage, the highest value of total carotenoids content was recorded in cultivar Lalit (139.32, 151.72 and 165.37 mg/100 g FW), followed by Allahabad Safeda (115.08, 122.32 and 128.85 mg/100 g FW), while lowest value was recorded in Shweta (98.65, 102.27 and 114.12 mg/100 g FW) at mature green, colour break and ripe stages, respectively. The carotenoid content in guava fruits increased with advancing maturity and had positive function in the epithelization process, affecting the cell cycle development of the fibroblasts. Guava is a good source of carotenoids content and it is a promising fruit for use in pharmacological products designed for antioxidant activity. With the onset of ripening, skin colour of guava fruits changes from green to yellow due to synthesis of carotenoids and/or the destruction of chlorophyll pigments [21]. The minimum carotenoid content might be associated with the delayed degradation of chlorophyll pigment. Reduction in the synthesis of carotenoids and delayed degradation of chlorophyll are correlated with each other [22].

Table 5 Effect of maturity stage on total carotenoids content (mg/100 g FW) of guava cultivars during storage at ambient condition

Maturity stages		Total carotenoids content (mg/100 g FW)				
		Days after storage (DAS)				
		0 DAS	3 DAS	6 DAS	9 DAS	12 DAS
Lalit	Mature green stage	42.84 ± 3.32 b	65.63 ± 4.05 c	86.62 ± 5.19 c	114.07 ± 3.56 b	139.32 ± 3.99 b
	Colour break stage	57.61 ± 5.72 b	73.89 ± 4.24 b	98.46 ± 4.72 b	126.49 ± 5.04 b	151.72 ± 5.48 ab
	Ripe stage	72.66 ± 5.01 a	96.24 ± 4.75 a	117.60 ± 4.31 a	145.41 ± 4.13 a	165.37 ± 6.15 a
Allahabad	Mature green stage	28.54 ± 1.42 b	43.71 ± 1.68 b	62.33 ± 4.65 b	84.72 ± 2.57 b	115.08 ± 3.78 b
Safeda	Colour break stage	39.32 ± 4.65 ab	51.26 ± 3.52 b	73.19 ± 5.12 b	95.61 ± 4.81 ab	122.32 ± 1.26 ab
	Ripe stage	46.18 ± 2.13 a	60.57 ± 2.15 a	83.56 ± 1.84 a	107.15 ± 3.58 a	128.85 ± 2.47 a
Shweta	Mature green stage	21.73 ± 1.44 b	35.87 ± 2.52 b	52.72 ± 5.34 b	76.28 ± 5.21 b	98.65 ± 3.08 b
	Colour break stage	32.95 ± 3.86 b	47.13 ± 1.89 ab	66.37 ± 3.42 ab	84.51 ± 1.95 ab	102.27 ± 4.62 b
	Ripe stage	40.16 ± 4.12 a	55.68 ± 2.63 a	72.26 ± 4.47 a	91.74 ± 4.32 a	114.12 ± 5.11 a

Malondialdehyde content (nmol/g FW)

The study revealed that malondialdehyde content of guava fruits showed a pronounced increased with advancement of storage period on 3rd, 6th, 9th and 12th days, respectively. However, during initial days and onwards, there was a significant difference observed in malondialdehyde content among mature green and ripe stage fruits, respectively in all the cultivars. The maximum malondialdehyde content was found at ripe stage, followed by colour break stage and the minimum malondialdehyde content was recorded at mature green stage. After 3 days of storage, out of different cultivars, Lalit showed maximum malondialdehyde content (0.82, 0.90 and 1.14 nmol/g FW), followed by Shweta (076, 0.84 and 1.02 nmol/g FW), whereas it was minimum in cultivar Allahabad Safeda (0.68, 0.75 and 0.92 nmol/g FW) at mature green, colour break and ripe stages, respectively. However, after 12 days of storage, the highest value of malondialdehyde content was recorded in cultivar Lalit (1.88, 2.07 and 2.42 nmol/g FW), followed by Shweta (1.67, 1.91 and 2.16 nmol/g FW), while lowest value was recorded in Allahabad Safeda (1.53, 1.68 and 1.96 nmol/g FW) at mature green, colour break and ripe stages, respectively. An increase in malondialdehyde content is associated with membrane injury in fruits, resulting in membranes rupture or shrivelling of fruit's skin. The final product of membrane lipid peroxidation is malondialdehyde, and its accumulation has been considered an important index for assessing the extent of

oxidative membrane damage in plant tissues. Lipid peroxidation rate depends on the balance between reactive oxygen species (ROS) production due to respiration and their utilisation by antioxidant systems [23]. Malondialdehyde content is an important indicator of cell oxidative damage and membrane injury [24-26].

Table 6 Effect of maturity stage on malondialdehyde content (nmol/g FW) of guava cultivars during storage at ambient condition

Maturity stages		Malondialdehyde content (nmol/g FW)				
		Days after storage (DAS)				
		0 DAS	3 DAS	6 DAS	9 DAS	12 DAS
Lalit	Mature green stage	0.56 ± 0.03 b	0.82 ± 0.02 a	1.24 ± 0.03 a	1.52 ± 0.04 b	1.88 ± 0.02 b
	Colour break stage	0.65 ± 0.05 ab	0.90 ± 0.05 a	1.32 ± 0.09 a	1.74 ± 0.06 ab	2.07 ± 0.04 b
	Ripe stage	0.84 ± 0.06 a	1.14 ± 0.14 a	1.55 ± 0.13 a	1.92 ± 0.08 a	2.42 ± 0.07 a
Allahabad	Mature green stage	0.41 ± 0.03 b	0.68 ± 0.06 a	1.06 ± 0.05 a	1.28 ± 0.02 b	1.53 ± 0.15 b
Safeda	Colour break stage	0.53 ± 0.06 ab	0.75 ± 0.03 a	1.12 ± 0.12 a	1.37 ± 0.05 b	1.68 ± 0.03 b
	Ripe stage	0.61 ± 0.02 a	0.92 ± 0.08 a	1.17 ± 0.09 a	1.55 ± 0.06 a	1.96 ± 0.08 a
Shweta	Mature green stage	0.48 ± 0.05 b	0.76 ± 0.07 a	1.15 ± 0.02 a	1.39 ± 0.03 b	1.67 ± 0.05 b
	Colour break stage	0.57 ± 0.03 ab	0.84 ± 0.01 a	1.21 ± 0.07 a	1.59 ± 0.08 ab	1.91 ± 0.03 ab
	Ripe stage	0.64 ± 0.04 a	1.02 ± 0.05 a	1.32 ± 0.11 a	1.76 ± 0.07 a	2.16 ± 0.04 a

Values are mean ± standard error of three replicate determinations (n=3). According to HSD Tukey's test, values in the same column with different letters are significantly different ($p < 0.05$)

Table 7 Effect of maturity stage on total antioxidant capacity (µmol TE/g FW) of guava cultivars during storage at ambient condition

Maturity stages		Total antioxidant capacity (µmol TE/g FW)				
		Days after storage (DAS)				
		0 DAS	3 DAS	6 DAS	9 DAS	12 DAS
Lalit	Mature green stage	8.85 ± 0.37 a	7.99 ± 0.23 a	7.06 ± 0.36 a	5.37 ± 0.39 a	3.75 ± 0.45 a
	Colour break stage	7.62 ± 0.25 b	6.69 ± 0.31 b	5.75 ± 0.27 b	4.83 ± 0.34 ab	3.37 ± 0.25 ab
	Ripe stage	6.10 ± 0.18 c	5.35 ± 0.22 c	4.74 ± 0.31 b	3.98 ± 0.27 b	3.12 ± 0.24 b
Allahabad	Mature green stage	6.34 ± 0.43 a	5.78 ± 0.56 a	4.52 ± 0.95 a	3.71 ± 0.20 a	3.09 ± 0.41 a
Safeda	Colour break stage	5.26 ± 0.35 b	4.81 ± 0.61 a	4.07 ± 0.69 ab	3.42 ± 0.37 a	2.87 ± 0.19 ab
	Ripe stage	4.55 ± 0.18 c	3.92 ± 0.84 b	3.34 ± 0.31 b	2.78 ± 0.51 b	2.42 ± 0.53 b
Shweta	Mature green stage	5.19 ± 0.27 a	4.76 ± 0.39 a	4.17 ± 0.49 a	3.65 ± 0.83 a	2.96 ± 0.72 a
	Colour break stage	4.42 ± 0.81 b	3.91 ± 0.78 ab	3.43 ± 0.77 b	2.94 ± 0.96 b	2.38 ± 0.28 b
	Ripe stage	4.05 ± 0.79 b	3.67 ± 0.86 b	3.18 ± 0.55 b	2.56 ± 0.09 c	2.11 ± 0.65 b

Total antioxidant capacity (µmol TE/g FW)

It is evident from the figure that total antioxidant capacity decline gradually with the advancement of storage period up to the end of storage at ambient condition. A significant difference in total antioxidant capacity was recorded among mature green and ripe stage fruits, respectively in all the cultivars during storage. It was observed that total antioxidant capacity in guava fruits decreased from mature green to ripe stages of maturity during storage period. However, 3 days onwards, significant difference in total antioxidant content was recorded between the different maturity stages and cultivars on the guava fruits. Among various cultivars, Lalit showed maximum total antioxidant capacity (7.99, 6.69 and 5.35 µmol TE/g FW), followed by Allahabad Safeda (5.78, 4.81 and 3.92 µmol TE/g FW), whereas it was minimum in cultivar Shweta (4.76, 3.91 and 3.67 µmol TE/g FW) at mature green, colour break and ripe stages, respectively. However, after 12 days of storage period, the maximum value of total antioxidant capacity was observed in cultivar Lalit (3.75, 3.37 and 3.12 µmol TE/g FW), followed by Allahabad Safeda (3.09, 2.87 and 2.42 µmol TE/g FW), while minimum value was recorded in Shweta (2.96, 2.38 and 2.11 µmol TE/g FW) at mature green, colour break and ripe stages, respectively. Antioxidant properties in guava fruits were found to decrease in over ripe stages of maturity from immature green stage. Storage intervals affected antioxidant activity significantly decreased, as the storage period advanced. Antioxidant capacity of fruit is contributed by several bioactive compounds like phenolics, flavonoids and ascorbic acid. These findings are corroborated with the outcomes of [27-29] in guava fruits. Total antioxidant capacity is contributed by the bioactive compounds present in fruits particularly vitamins (ascorbic acid), polyphenols, flavonoids, etc. [30-31].

Decay loss (%)

In this experiment, decay showed an increasing trend over time as storage duration advances. There was very less sign of decay until 3 days of storage period. Among different maturity stages, minimum decay loss was observed at mature green stage, followed by colour break stage and maximum decay loss was noted at ripe stage. Out of different cultivars, after 6 days onwards, Allahabad Safeda showed minimum decay loss (0.00, 5.55 and 11.11%), followed by Shweta (2.77, 8.33 and 16.66%), whereas it was maximum in cultivar Lalit (5.55, 11.11 and 22.22%) at mature green, colour break and ripe stages, respectively. However, after 12 days of storage, lowest value of decay loss was recorded in cultivar Allahabad Safeda (19.42, 30.55 and 41.46%), followed by Shweta (22.22, 36.11 and 49.99%), while the highest value was noted in Lalit (30.55, 44.44 and 63.77%) at mature green, colour break and ripe stages, respectively. During the study, Allahabad Safeda showed minimum decay loss, followed by Shweta, whereas it was maximum in cultivar Lalit. Decay percentage is very significant for any perishable commodity. Since, guava fruits undergo rapid softening within few days of storage due to ripening, it become susceptible to attack by various disease-causing microorganisms which are responsible for rapid decay. Fruit decay may be caused by fungi. Rot turns fruits mushy, and affected fruits have foul odours as a result of their underlying

biochemical changes. Similar outcomes were recorded by Nasrin *et al*. [32], (2018) in mandarin, Farahi [33] in table grape, Gad and Zagzog [34] and Singh *et al*. [35] in guava fruits, respectively.

Table 8 Effect of maturity stage on decay loss (%) of guava cultivars during storage at ambient condition

Maturity stages		Total Antioxidant capacity (µmol TE/g FW)				
		Days after storage (DAS)				
		0 DAS	3 DAS	6 DAS	9 DAS	12 DAS
Lalit	Mature green stage	0	0	5.55 ± 2.78 b	13.88 ± 2.77 b	30.55 ± 2.78 c
	Colour break stage	0	0	11.11 ± 2.77 b	22.22 ± 2.78 b	44.44 ± 2.78 b
	Ripe stage	0	13.88 ± 2.78 a	22.22 ± 2.78 a	44.44 ± 2.78 a	63.77 ± 2.89 a
Allahabad	Mature green stage	0	0	0	8.33 ± 4.80 b	19.42 ± 2.78 b
Safeda	Colour break stage	0	0	5.55 ± 2.77 ab	13.77 ± 2.72 ab	30.55 ± 2.78 ab
	Ripe stage	0	0	11.11 ± 4.81 a	24.87 ± 4.91 a	41.66 ± 4.81 a
Shweta	Mature green stage	0	0	2.77 ± 1.22 b	11.11 ± 2.77 b	22.22 ± 2.78 c
	Colour break stage	0	0	8.33 ± 2.78 ab	19.33 ± 2.83 ab	36.11 ± 2.78 b
	Ripe stage	0	5.55 ± 2.78 a	16.66 ± 4.81 a	30.55 ± 2.78 a	49.99 ± 4.81 a

Values are mean ± standard error of three replicate determinations (n=3). According to HSD Tukey's test, values in the same column with different letters are significantly different ($p < 0.05$)

CONCLUSION

The findings of the experiment revealed that the stage of maturity or ripeness at harvest had a significant effect on storage life and quality of guava fruits. Among different maturity stages, mature green stage showed promising results in delaying the physico - chemical changes as compared to colour turning stage and ripe stage of fruits. Considering all the parameters, Lalit and Allahabad Safeda cultivars of guava were identified as the best cultivars in terms of better post-harvest life, whereas Lalit excelled in terms of maximum total chlorophyll content, total carotenoids content, total antioxidant content, and minimum acidity content. Allahabad Safeda cultivars showed minimum weight loss and decay loss.

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