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Effect of chemical 1-MCP of deferring senescence of guava (*Psidium guajava*)

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Abstract
The guava fruit (*Psidium guajava*) is a tropical fruit that is available during specific seasons. It is packed with antioxidants, vitamin C, and polyphenol compounds. However, when kept under normal conditions, the fruit cannot be stored for an extended duration because it ripens quickly, becomes soft suddenly, and is prone to fungal growth. The objective of this study was to examine how treating guava fruits with 1-methylcyclopropene (1-MCP) influences the process of senescence and the overall physicochemical quality of the fruits after they are harvested. The fruits were subjected ton were immersed in different concentrations of 1-MCP (300, 600, 900, and 1200 nLL^{-1}) for 15 minutes, while a control group was immersed in distilled water and stored for 12 days at ambient conditions. The findings indicated that the application of 1-MCP at a concentration of 600 nLL^{-1} resulted in the lowest weight loss (10.95%) compared to the control group. It also effectively maintained the highest level of firmness (4.36 mg/cm^2), whereas the control group exhibited the lowest firmness. The occurrence of decay was minimized (22%) in the 1-MCP (600 nLL^{-1}) treated group, while the control group experienced the highest decay rate (50.67%). Additionally, the 1-MCP treatment (600 nLL^{-1}) played a significant role in preserving the fruit's quality by reducing the degradation of total soluble solids (TSS), highest brix-acid ratio and highest level of non-reducing sugars compared to the control group. Furthermore, the 1-MCP treatment (600 nLL^{-1}) contributed to maintaining the maximum content of ascorbic acid, antioxidants, flavonoids, and total sugars. 1-MCP also retained the highest percentage of reducing sugars and titratable acidity in the fruits. Based on organoleptic parameters such as aroma, texture, flavor, and appearance, the 1-MCP treatment at 600 nLL^{-1} received the highest overall acceptability rating of 5.88 at the end of the storage period.

Keywords: 1- methylcyclopropene, 1-MCP, decay, senescence, organoleptic, quality, guava, firmness, total sugars, antioxidants, flavonoid, ascorbic acid

Introduction
Guava, (*Psidium guajava*) is globally renowned for its culinary and nutritional significance. It is thought that the origin of guava can be traced back to either Mexico or Central America. Guava has gained immense popularity in Asian nations and its availability is gradually increasing in American countries as well. The leading guava-producing countries include India, China, Thailand, Pakistan, Mexico, Indonesia, Brazil, Bangladesh, the Philippines, and Nigeria (Parvez *et al*., 2018) [1]. India holds the position of being the largest global producer of guava, responsible for 45% of the total production worldwide (Rawan *et al*., 2017) [2]. Uttar Pradesh, with a guava production of 0.98 million metric tonnes, takes the lead as the top guava-producing state in India. This state accounts for 21.78% of the total area dedicated to guava cultivation (APEDA 2021-22) [3]. Due to its various medicinal properties, guava is commonly known as the "common man's apple" (Irshad *et al*, 2020) [4].
Guava is affluent in vitamin C and contains significant amounts of manganese, fiber, pyridoxine (vitamin B6), and niacin (vitamin B9) (Ghodake *et al*., 2022) [5]. Guava also provides an abundant supply of phytochemicals, including polysaccharides, lycopene, vitamins, essential oils, lutein, lectins, zeaxanthin, tannins, dietary fiber, phenols, triterpenes, saponins, carotenoids, and fatty acids (Joseph and Priya, 2011) [6]. Guava offers a wide range of value-added products that showcase its versatility. These include guava juice, guava pulp, guava nectar, jam, and jelly, guava-flavored toffees. Furthermore, guava can be utilized as an additive to enhance the flavor and nutritional profile of other fruit juices or pulps (Kumari *et al*., 2017) [7]. Different components of the plant are employed within diverse indigenous medicinal practices, primarily aimed at addressing gastrointestinal ailments (Akanda *et al*., 2018) [8]. The fruit showcases notable antioxidant characteristics, such as quercetin, and possesses radio-protective capabilities (Naseer *et al*., 2018) [9].

As a climacteric fruit, guava undergoes ongoing physicochemical changes after being harvested until it reaches a state where it becomes unsuitable for consumption very quickly (Rana *et al*., 2015) [10]. Also, the quality and market value of guava can be impacted by several other factors, such as fruit fly infestation, post-harvest diseases like stem end rot and anthracnose, as well as chilling injury (Meena *et al*., 2021) [11]. Different approaches are implemented to extend the shelf life of guava and slow down its senescence process. 1-Methylcyclopropene (1-MCP), an ethylene perception inhibitor, is commonly used to preserve the quality of climacteric fruits during storage by reducing ethylene perception (Zhang *et al*., 2020) [12]. The research aims to investigate the impact of 1-MCP on both the shelf life and overall quality of guava. The study specifically focuses on evaluating the sensory attributes of guava following treatment with this antiethylene compound. Guava fruits are treated with different concentrations of 1-MCP (300, 600, 900, and 1200 nLL^{-1}) to reduce ethylene synthesis and respiration rates. The impact of these treatments on the shelf life and quality of the fruits is then evaluated.

Material and Methods

The 'Allahabad Safeda' variety of guava fruits was sourced from the orchard at Lovely Professional University, Punjab in 2022. Only well-matured guava fruits of consistent size were selected for the study. Furthermore, the fruits were carefully chosen based on their overall health, ensuring they were free from diseases and skin bruises. After that fruits were transported to laboratory of the university and fruits were subject to immersing treatments for 15 minutes with chemical 1-MCP (1-methylcyclopropene) at concentrations 300, 600, 900 and 1200 nLL^{-1}. The control fruits were treated with distilled water for 15 minutes. After the treatments fruits were dried in fan for 10 minutes and then stored in ambient conditions at temperature (20±1 ºC) and 50% relative humidity for 12 days and analyzed every 3rd day.

Physical parameters determination:

The physiological loss in weight (PLW) was determined at every 3rd day by subtracting the weight of fruit on day from the weight taken initially and dividing the whole by initial weight of fruit, and the outcomes were expressed as a percentage (%). Whereas, the firmness of guava fruits was evaluated using a penetrometer, and the measurement of fruit firmness was expressed in Kg/cm^2. Also, the calculation for fruit degradation loss involved counting the number of healthy and diseased guava fruits in each treatment and dividing the decayed fruits by total number of fruits. It is expressed in percentage (%).

Quality parameters determination:

To measure the TSS (Total Soluble Solids) content in guava fruit a digital refractometer was employed. The TSS value was quantified and reported in ºBrix units. Titratable acidity was determined by titration. In this method, a flask containing a mixture of 10 mL of juice and water was titrated against sodium hydroxide 0.1 N (4g/1000g) solution. Phenolphthalein was employed as an indicator during the process. The final value obtained was expressed as a percentage (%). The ratio between Brix and acidity of the fruit was aquired by dividing the Total Soluble Solids (TSS) by the titratable acidity (TA). The assay method was employed to measure the ascorbic acid content in guava. To perform this method, a 3% solution of metaphosphoric acid (HPO_3), a standard ascorbic acid solution, and indophenol (2,6-dichlorophenol indophenol) dye were prepared. Initially, a titration of the standard ascorbic acid solution against the dye was conducted to determine the dye factor. Subsequently, a solution was prepared by combining 10 grams of the guava sample with 100 mL of 3% metaphosphoric acid. A 10 mL portion of the resulting filtrate was used and titrated against the dye. The endpoint was indicated by the appearance of a pink color. The evaluation of antioxidant activity involved the use of the stable 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical. Initially, 500 mg of fruit pulp was dissolved in 10 mL of methanol and then underwent centrifugation at 4,000 rpm for 15 minutes. The supernatant was taken and further diluted with methanol to assess the antioxidant activity. A spectrophotometer was used to measure the absorbance at 517 nm. The percentage of DPPH scavenging was calculated based on the absorbance. The blank sample consisted of the dye mixed with 0.5 mL of methanol. The values for antioxidants were determined and expressed as a percentage (%).In order to determine the flavonoid content, a mixture was prepared using 1.0 mL extract of guava fruit was combined with 0.3 mL of a 5% sodium nitrite solution, 4.0 mL of distilled water, and methanol in a test tube. Following that, 0.3 mL of a 10% aluminum chloride solution was added. After allowing it to stand for 6 minutes, 2.0 mL of 1.0 N sodium hydroxide and distilled water were added to bring the total volume to 10 mL. The absorbance at 510 nm was then measured. The flavonoid content was expressed as milligrams of catechin equivalent per 100 grams of fresh weight.

For the analysis of sugar content, a combination of 20 mL of guava juice and 5 mL of concentrated HCL was created. To neutralize any excess acid, a sodium carbonate solution was employed. The resulting solution was then transferred to a volumetric flask and diluted with distilled water. Subsequently, the solution was titrated using Fehling's solutions A and B, employing a burette, as part of the sugar reduction process. The calculation of the percentage of total sugars involved dividing 0.25 by the reading obtained from the burette. To determine the reducing sugars, Nelson's method was employed. In this method, 5 mL each of Fehling's "A" and "B" solutions were combined with 40 mL of distilled water. The fruit juice solution was then gradually added from a burette to the heated Fehling's solution until a faint red hue was observed. Methylene blue was used as an indicator, and titration was performed until the formation of a reddish-brown precipitate, indicating the endpoint. The percentage of reducing sugar was calculated by dividing 0.25 by the reading obtained from the burette. Non-reducing sugars were determined by subtracting the value of reducing sugars from the total sugar content and expressed in percentage (%).

Samples were assessed for sensory attributes including aroma, texture, flavor, and appearance by a panel of five individuals. Each panelist filled out a consent form, providing information about the chemicals used in the emulsions and any potential allergic reactions. Each panelist had around 10 minutes to complete a questionnaire, rating the samples on a hedonic scale ranging from 1 (strong dislike) to 9 (strong liking).

The experimental setup included 40 fruits for each treatment, with three replications. The trials were arranged based on a factorial completely randomized design (CRD). The data collected from the experiment were analyzed using OPSTAT

software, following the design parameters.

Result and Discussion

1-MCP (1- methylcyclopropene) had prominent effect on physical (PLW, firmness, decay percentage), quality (TSS, titratable acidity, ascorbic acid content, antioxidants, flavonoid content, brix- acid ratio, total sugars, reducing and non-reducing sugars) and organoleptic (aroma, texture, flavour, appearance) parameters of guava fruits when stored at ambient storage conditions for 12 days after treatment as compared to controlled (untreated) ones.

Physical parameters

Physiological loss in weight (%)

The study finds out that fruits treated with 1-MCP maintained more weight as compared to untreated ones (control) (Table 1 and Fig. 1). At the end of storage maximum weight loss (21.12%) was found in treatment T_1 that was control and minimum weight loss (10.95%) was observed in treatment T_3 that was 1-MCP at 600 nLL^{-1}. The application of 1-MCP treatments resulted in a notable reduction in weight loss this may be due to 1-MCP impeding the ripening process through the suppression of ethylene receptors (Kumar *et al*., 2020) [13]. This agrees with the study in banana (Satekge *et al*., 2020) [14], mango cv. Alphonso (Gaikwad *et al*., 2020) and mango cv. Kesar (Sakhale *et al*., 2018) [15].

Table 1: Effect of 1-MCP on physiological loss in weight- PLW (%) of guava fruits

	Treatments	3rd day	6th day	9th day	12th day	Average
T_1	Control	4.38 (12.07)*	10.23 (18.65)*	15.27(22.99)*	54.60 (47.62)**	21.12 (24.26)*
T_2	300 nLL^{-1} 1-MCP	3.77 (11.19)*	9.46 (17.91)*	14.19 (22.12)*	53.19 (46.81)**	20.15 (23.66)*
T_3	600 nLL^{-1} 1-MCP	3.23 (10.34)*	8.76 (17.21)*	13.88 (21.87)*	17.93 (25.04)*	10.95 (17.21)*
T_4	900 nLL^{-1} 1-MCP	3.81 (11.25)*	9.55 (18.00)*	14.19 (22.12)*	54.07 (47.32)*	20.41 (23.82)*
T_5	1200 nLL^{-1} 1-MCP	3.76 (11.18)*	9.60 (18.04)*	14.41 (22.30)*	54.87 (47.78)*	20.66 (23.98)*
	CD at 5%	0.15	0.16	0.12	2.85	0.56
	SE(m)	0.05	0.05	0.04	0.89	0.18

*Transformed value, **Sign-transformed value of physiological loss in weight

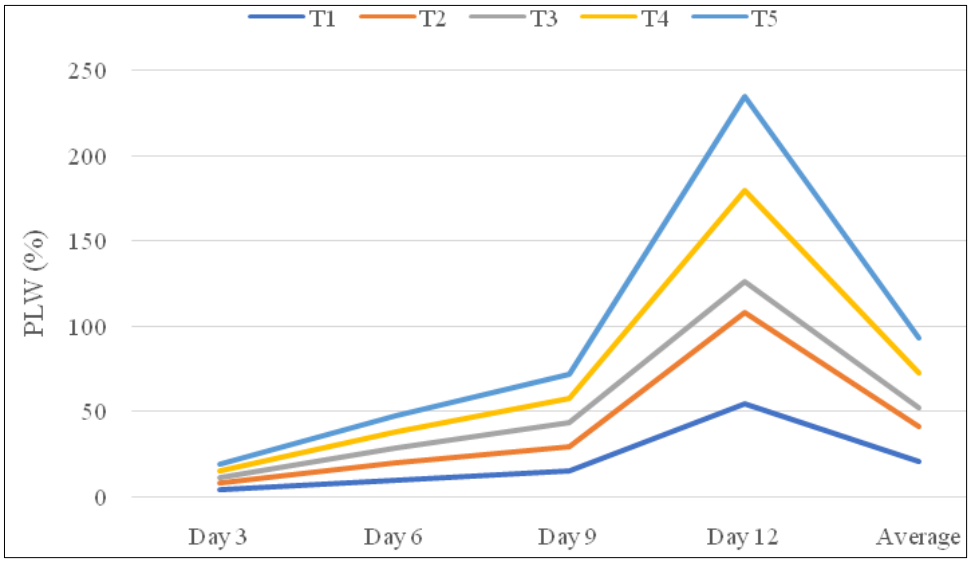

Fig 1: Effect of 1-MCP on physiological loss in weight (%) of guava fruits

Firmness (Kg/cm^2)

During storage fruits treated with 1-MCP maintained more firmness as compared to controlled ones (Table 2). Maximum firmness was (4.36 kg/cm^2) that were maintained by treatment T_3 (1-MCP 600 nLL^{-1}) and minimum was (3.44 kg/cm^2) in treatment T_1 that was control. Fruits treated with 1-MCP are better than control may be because the application of 1-MCP could potentially decrease in enzyme activity (pectinesterase (PE), endo-polygalacturonase (endo-PG), exo-polygalacturonase (exo-PG), and endo-β-1,4-glucanase (EGase)) account for the observed reduction in fruit softening (Li *et al*., 2020) [16]. Resembling results are shown in nectarine (Ozkaya *et al*., 2016) [17], apple var. Hwangok (Win *et al*., 2021) [18] and 'Idared' apple (Tomala *et al*., 2020) [19].

Table 2: Effect of 1-MCP on firmness (Kg/cm^2) of guava fruits

	Treatments	0th day	3rd day	6th day	9th day	12th day	Average
T_1	Control	6.11	4.95	2.98	1.94	1.19	3.44
T_2	300 nLL^{-1} 1-MCP	6.21	5.11	3.27	2.27	1.37	3.65
T_3	600 nLL^{-1} 1-MCP	6.51	5.32	4.28	3.25	2.44	4.36
T_4	900 nLL^{-1} 1-MCP	5.98	4.97	3.30	2.27	1.57	3.62
T_5	1200 nLL^{-1} 1-MCP	6.22	5.08	3.57	2.18	1.56	3.72
	CD at 5%	0.19	N/A	0.46	0.36	0.36	0.19
	SE(m)	0.06	0.10	0.14	0.11	0.11	0.06

Decay percentage (%)

Fruits treated with 1-MCP had minimum decay at the end of storage as compared to controlled fruits (Table 3). Minimum decay (22%) was observed in treatment T_3 (1-MCP 600 nLL^{-1}) and maximum decay (50.67%) was found in treatment T_1 (control). The gradual decline in quality observed in fruits treated with 1-MCP can be attributed to its ability to inhibit ethylene effects and minimize chilling damage. Extensive research has demonstrated the successful reduction in fruit deterioration rates following harvest with the use of 1-MCP. Consequently, it holds considerable promise for extending the shelf life of fruits (Thakriya *et al*., 2022) [20]. Similar results found in guava (Iqbal *et al*., 2018) [21] and apple (Li *et al*., 2017) [22].

Table 3: Effect of 1-MCP on decay percentage (%) of guava fruits

Treatment		Decay (%)	
		Mean	S.E.
T_1	Control	50.67 (45.36)**	0.67
T_2	1-MCP (300 nLL^{-1})	38.67 (38.43)**	0.67
T_3	1-MCP (600 nLL^{-1})	22.00 (27.95)*	1.16
T_4	1-MCP (900 nLL^{-1})	33.33 (35.24)**	1.33
T_5	1-MCP (1200 nLL^{-1})	36.00 (36.84)**	2.00
C.D. at 5%		7.18	
SE(m)		2.25	

*Transformed value, **Sign-transformed values

Quality parameters

Total soluble solids (ºBrix)

Study finds out that maximum TSS (12.40 ºbrix) was found in controlled fruits treatment T_1 and minimum TSS (12.08 ºbrix) was observed in treatment T_3 (1-MCP 600 nLL^{-1}) (Table 4 and Fig. 2). 1-MCP maintained less TSS than control that might be due to the metabolic activity of fruits during the ripening process is hindered by the application of 1-MCP, which aids in the preservation of the total soluble solids (TSS) value (Mubarok *et al*., 2022) [23]. Results were in accordance with study by (Kurubas *et al*., 2018) [24] in pears, by (Sakhale *et al*., 2018) [15] in mango cv. Kesar and by (Krishnakumar *et al*., 2014) [25] in banana.

Table 4: Effect of 1-MCP on TSS (^{0}Brix) of guava fruits

	Treatments	0th day	3rd day	6th day	9th day	12th day	Average
T_1	Control	12.07	12.42	13.59	12.09	11.85	12.40
T_2	300 nLL^{-1} 1-MCP	12.13	12.01	13.12	12.20	11.79	12.25
T_3	600 nLL^{-1} 1-MCP	12.16	11.85	12.92	11.99	11.48	12.08
T_4	900 nLL^{-1} 1-MCP	12.08	12.04	13.21	12.15	11.78	12.25
T_5	1200 nLL^{-1} 1-MCP	12.37	12.03	12.61	12.08	11.64	12.15
	CD at 5%	N/A	0.29	0.48	N/A	0.24	0.16
	SE(m)	0.07	0.09	0.15	0.09	0.08	0.05

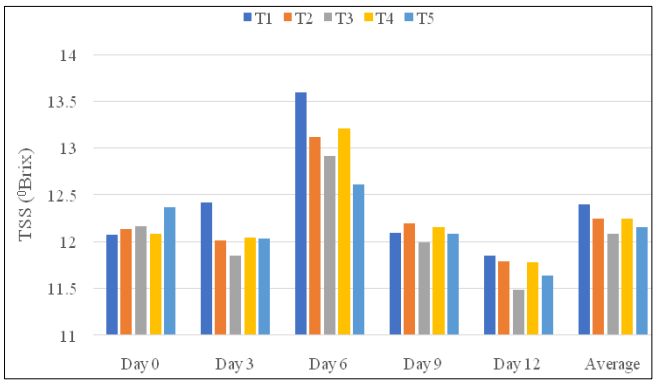

Fig 2: Effect of 1-MCP on TSS (ºBrix) of guava fruits

Titratable acidity (%)

Titratable acidity declines with storage and therefore maximum (0.52%) titratable acidity at the end of storage was maintained by treatment T_3 (1-MCP 600 nLL^{-1}) whereas, controlled fruits (T_1) resulted in maintain the lowest titratable acidity (0.48%) (Table 5 and Fig. 3). 1-MCP maintained more titratable acidity than control that might because it restrains the conversion of acids (breakdown of organic acids) during the ripening process and aids in preserving acidity levels (Mubarok *et al*., 2022) [23]. Alike results were found in pear (Kurubas *et al*., 2018) [24], kiwi fruits (Chai *et al*., 2021) [26] and 'Empire' apple (Saba *et al*., 2020) [27].

Table 5: Effect of 1-MCP on titratable acidity-TA (%) of guava fruits

	Treatments	0th day	3rd day	6th day	9th day	12th day	Average
T_1	Control	0.60	0.55	0.49	0.42	0.36	0.48
T_2	300 nLL^{-1} 1-MCP	0.64	0.56	0.51	0.43	0.38	0.50
T_3	600 nLL^{-1} 1-MCP	0.63	0.60	0.52	0.45	0.38	0.52
T_4	900 nLL^{-1} 1-MCP	0.60	0.56	0.49	0.44	0.37	0.49
T_5	1200 nLL^{-1} 1-MCP	0.62	0.56	0.49	0.44	0.37	0.50
	CD at 5%	0.02	0.02	0.03	0.02	0.01	0.02
	SE(m)	0.01	0.01	0.01	0.01	0.00	0.01

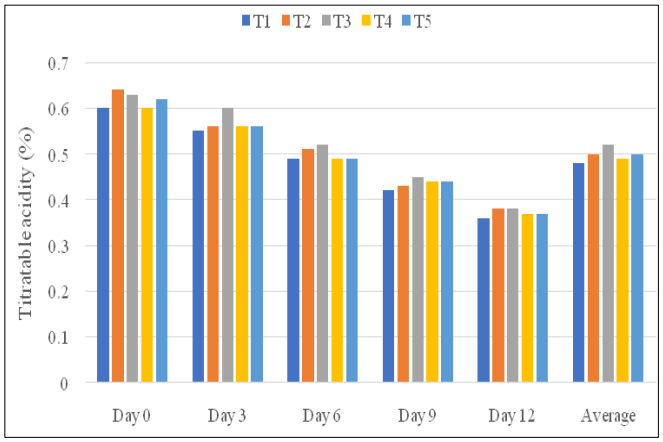

Fig 3: Effect of 1-MCP on titratable acidity- TA (%) of guava fruits

Ascorbic acid content (mg/100gm)

According to the study it can be seen that at the end of storage more ascorbic acid content was maintained in fruits treated with 1-MCP as compared to untreated ones (Table 6 and Fig. 4). Maximum (167.64 mg/100gm) ascorbic acid content was observed in treatment T_3 (1-MCP 600 nLL^{-1}). Minimum

(137.04 mg/100gm) ascorbic acid was found in treatment T_1 (control). 1-MCP maintained more ascorbic acid content than controlled ones that might because the active sites for ethylene, were effectively blocked by 1-MCP. This inhibition of the ripening process resulted in a notable delay in the abrupt decline of ascorbic acid concentration (Gaikwad *et al*., 2020) [28]. Similar results were shown in mango cv. Kesar (Sakhale *et al*., 2018) [15], peach (Liu *et al*., 2015) [29] and mulberries (Oz *et al*., 2014) [30].

Table 6: Effect of 1-MCP on Ascorbic acid (mg/100gm) concentration of guava fruits

	Treatments	0th day	3rd day	6th day	9th day	12th day	Average
T_1	Control	195.70	153.17	132.56	110.93	92.83	137.04
T_2	300 nLL^{-1} 1-MCP	198.55	179.67	155.21	118.10	105.33	151.37
T_3	600 nLL^{-1} 1-MCP	195.43	200.25	179.02	149.81	113.67	167.64
T_4	900 nLL^{-1} 1-MCP	197.73	192.71	165.49	121.96	105.13	156.60
T_5	1200 nLL^{-1} 1-MCP	197.59	185.80	165.60	125.08	105.52	155.92
	CD at 5%	1.90	3.76	4.36	3.65	3.66	1.82
	SE(m)	0.60	1.18	1.37	1.14	1.15	0.57

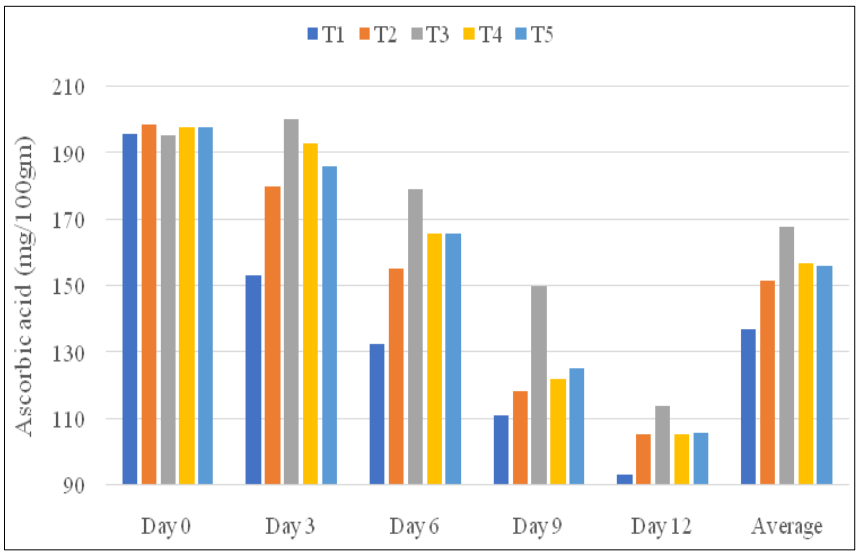

Fig 4: Effect of 1-MCP on ascorbic acid content (mg/100gm) of guava fruits

Antioxidants (%)

Antioxidants decreases with storage of fruits. Therefore, fruits treated with 1-MCP were able to maintain more antioxidants at the end of storage as compared to untreated (controlled) ones (Table 7 and Fig. 5). Maximum (37.14%) ascorbic acid was found in treatment T_3 (1-MCP 600 nLL^{-1}) and minimum (35.56%) ascorbic acid content was found in treatment T_1 (control). 1-MCP maintained higher antioxidants than control that could be due to the utilization of 1-MCP treatment potentially influenced the control of excessive reactive oxygen species (ROS) production and hindered lipid peroxidation over the duration of storage. Moreover, the use of 1-MCP significantly maintained elevated levels of catalase (CAT), peroxidase (POD), and superoxide dismutase (SOD) activities throughout the storage period (Li *et al*., 2020) [16]. The results were in accordance with loquat (Cao *et al*., 2011) [31] and peach (Jinn *et al*., 2011) [32].

Table 7: Effect of 1-MCP on antioxidants (%) value of guava fruits

	Treatments	0th day	3rd day	6th day	9th day	12th day	Average
T_1	Control	43.18	40.22	37.13	31.19	26.08	35.56
T_2	300 nLL^{-1} 1-MCP	43.19	41.22	37.58	32.27	26.64	36.18
T_3	600 nLL^{-1} 1-MCP	43.32	41.61	38.30	33.26	29.21	37.14
T_4	900 nLL^{-1} 1-MCP	43.06	41.26	37.58	32.14	26.07	36.02
T_5	1200 nLL^{-1} 1-MCP	43.25	41.28	37.63	32.21	26.07	36.09
	CD at 5%	0.10	0.11	0.13	0.12	0.09	0.06
	SE(m)	0.03	0.03	0.04	0.04	0.03	0.02

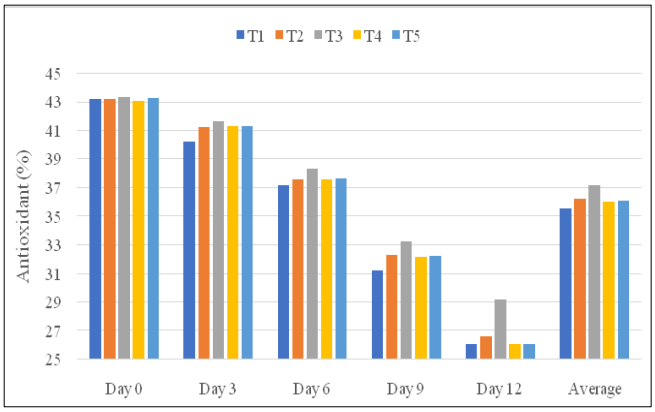

Fig 5: Effect of 1-MCP on antioxidants (%) of guava fruits

Flavonoid content (mg/100gm)

Flavonoid content in fruits decreases gradually with storage. Although 1-MCP treated fruits were able to maintain more flavonoid content as compared to untreated (controlled) fruits (Table 8 and Fig. 6). Maximum (21.40 mg/100gm) flavonoid content was maintained in treatment T_3 (1-MCP 600 nLL^{-1}) and minimum (20.32 mg/100 gm) flavonoid content was found in treatment T_1 (control). Fruits subjected to 1-MCP treatment exhibit a decelerated degradation rate of flavonoids in comparison to the control group. This phenomenon can be attributed to the fact that 1-MCP reduces cellular oxidative

stress levels and enhances the enzymatic antioxidant capacity within the tissue (Cao *et al*., 2011) [31]. Results were in accordance with study by (Xu *et al*., 2020) [33] in Huangguan pears, by (Zhang *et al*., 2013) [34] in avocado and by (Ozturk *et al*., 2021) [35] in jujube.

Table 8: Effect of 1-MCP on flavonoid content (mg/100 gm) of guava fruits

	Treatments	0th day	3rd day	6th day	9th day	12th day	Average
T_1	Control	24.13	23.10	21.13	18.17	15.07	20.32
T_2	300 nLL^{-1} 1-MCP	24.06	23.53	21.13	18.62	15.69	20.61
T_3	600 nLL^{-1} 1-MCP	24.24	23.65	22.59	19.22	17.28	21.40
T_4	900 nLL^{-1} 1-MCP	23.96	23.51	22.23	18.62	15.63	20.79
T_5	1200 nLL^{-1} 1-MCP	24.16	23.56	22.27	18.61	15.54	20.83
	CD at 5%	0.11	0.04	0.05	0.06	0.06	0.03
	SE(m)	0.04	0.01	0.01	0.02	0.02	0.01

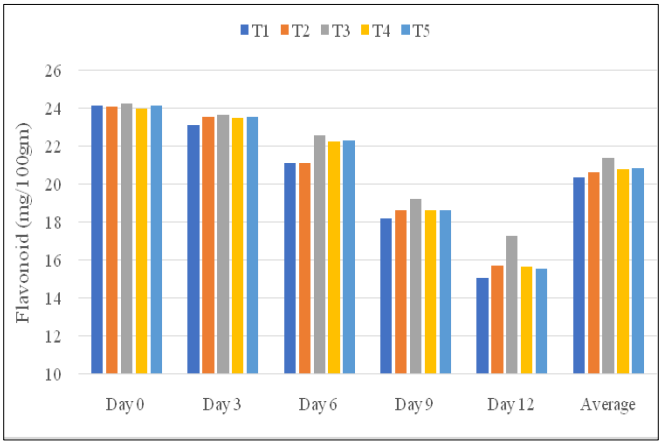

Fig 6: Effect of 1-MCP on flavonoid content (mg/100 gm) of guava fruits

Brix-acid ratio

Among all the treatments it can be seen that maximum (24.24) brix-acid ratio was maintained by treatment T_3 (1-MCP 600 nLL^{-1}) and minimum (26.44) brix-acid ratio was found in treatment T_1 (control) (Table 9 and Fig. 7). 1-MCP showed better results that might because the way 1-MCP works is by preventing ethylene receptors from functioning, which leads to the suppression of organic acid degradation and acid synthesis during the ripening process (Mubarok *et al*., 2022) [23]. Alike results were found in tomato (Park *et al*., 2016) [36] and Kensington Pride mango (Razzaq *et al*., 2016) [37].

Table 9: Effect of 1-MCP on Brix-acid ratio of guava fruits

	Treatments	0th day	3rd day	6th day	9th day	12th day	Average
T_1	Control	20.01	22.59	27.94	29.03	32.62	26.44
T_2	300 nLL^{-1} 1-MCP	18.96	21.45	25.94	28.63	31.05	25.21
T_3	600 nLL^{-1} 1-MCP	19.40	19.75	25.04	26.76	30.22	24.24
T_4	900 nLL^{-1} 1-MCP	20.13	21.50	26.97	28.08	31.86	25.71
T_5	1200 nLL^{-1} 1-MCP	20.07	21.49	25.73	27.43	31.19	25.18
	CD at 5%	0.56	1.03	N/A	1.39	1.51	0.82
	SE(m)	0.18	0.32	0.42	0.44	0.47	0.26

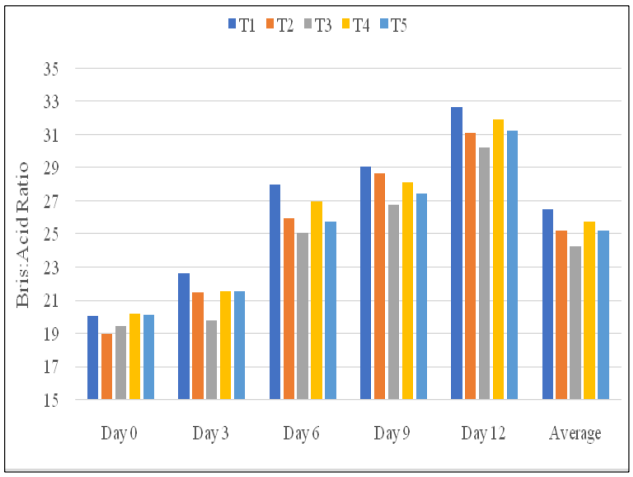

Fig 7: Effect of 1-MCP on brix-acid ratio of guava fruits

Total sugars (%)

The study illustrate that untreated fruits maintained lowest of total sugars while treated fruits maintained more level of total sugars in guava fruits (Table 10 and Fig. 8). Maximum (12.28%) total sugars were maintained in treatment T_3 (1-MCP 600 nLL^{-1}). Minimum (11.83%) total sugars were observed in treatment T_1 (control). The decrease in total sugar content and sucrose levels observed following the application of 1-MCP treatment can be attributed to a reduction in the conversion of starch into sugars (Razzaq *et al*., 2016) [37]. Results were in accordance with study by (Cao *et al*., 2011) [31] in loquat and by (Lee *et al*., 2017) [38] in Fuji apple.

Table 10: Effect of 1-MCP on total sugars (%) present in guava fruits

	Treatments	0th day	3rd day	6th day	9th day	12th day	Average
T_1	Control	11.05	11.64	14.56	12.59	9.31	11.83
T_2	300 nLL^{-1} 1-MCP	11.23	11.91	14.95	13.00	10.04	12.23
T_3	600 nLL^{-1} 1-MCP	11.08	11.93	15.12	13.10	10.15	12.28
T_4	900 nLL^{-1} 1-MCP	11.06	11.90	14.93	12.87	10.05	12.16
T_5	1200 nLL^{-1} 1-MCP	11.15	11.92	14.93	12.86	9.88	12.15
	CD at 5%	0.11	0.20	0.10	0.10	0.14	0.07
	SE(m)	0.04	0.06	0.03	0.03	0.04	0.02

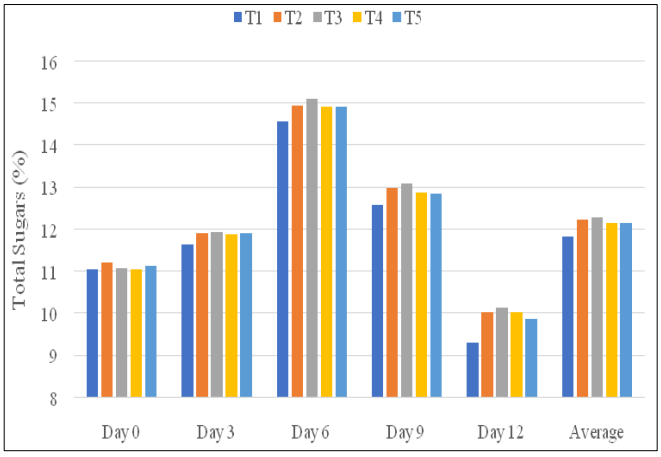

Fig 8: Effect of 1-MCP on total sugars (%) of guava fruits

Reducing sugars (%)

Study reveals that fruits treated with 1-MCP maintained more reducing sugars as compared to untreated fruits (control) at the end of storage (Table 11 and Fig. 9). Maximum (7.77%)

total sugars were observed in treatment T_3 (1-MCP 600 nLL^{-1}). Minimum (7.63%) reducing sugars were maintained in treatment T_1 (control). The application of 1-MCP treatment on fruits decreased sugar degradation compared to the control group, attributed to reduced respiration rate and delayed ripening. This treatment also led to a decrease in overall sugar content and sucrose levels, linked to reduced conversion of starch into sugars (Razzaq *et al*., 2016 and Satekge *et al*., 2020) [37, 14]. Results were alike with Fuji apple (Lee *et al*., 2017) [38] and banana (Zewter *et al*., 2012) [39].

Table 11: Effect of 1-MCP on reducing sugars (%) of guava fruits

	Treatments	0th day	3rd day	6th day	9th day	12th day	Average
T_1	Control	6.79	8.13	9.15	8.39	5.70	7.63
T_2	300 nLL^{-1} 1-MCP	6.77	8.16	9.16	8.39	6.31	7.76
T_3	600 nLL^{-1} 1-MCP	6.82	8.11	9.12	8.38	6.45	7.77
T_4	900 nLL^{-1} 1-MCP	6.87	8.13	9.15	8.37	6.29	7.76
T_5	1200 nLL^{-1} 1-MCP	6.78	8.13	9.13	8.40	6.21	7.73
	CD at 5%	N/A	N/A	N/A	N/A	0.04	0.03
	SE(m)	0.02	0.01	0.02	0.01	0.01	0.01

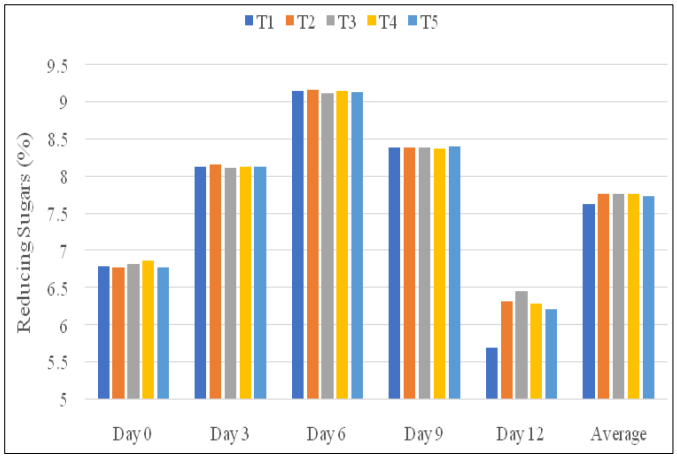

Fig 9: Effect of 1-MCP on reducing sugars (%) of guava fruits

Non-reducing sugars (%)

The study manifest that fruits treated with 1-MCP maintained more non-reducing sugars as compared to controlled ones at the end of storage (Table 12 and Fig. 10). Maximum (4.50%) non-reducing sugars were maintained in treatment T_3 (1-MCP 600 nLL^{-1}) and minimum (4.20%) were maintained in treatment T_1 (control). 1-MCP treatment reduced sugar degradation in fruits compared to the control group, likely due to decreased respiration and delayed ripening. The decline in sugar content and sucrose levels after treatment can be attributed to reduced starch conversion, enhancing fruit sweetness (Razzaq *et al*., 2016 and Satekge *et al*., 2020) [37, 14]. Similar results were observed in banana (Yassin *et al*., 2011) [40], apricot fruit cv. Canino (Radwa *et al*., 2019) [41] and in banana (Satekge *et al*., 2020) [14].

Table 12: Effect of 1-MCP on non-reducing sugars (%) of guava fruits

	Treatments	0th day	3rd day	6th day	9th day	12th day	Average
T_1	Control	4.26	3.51	5.41	4.20	3.61	4.20
T_2	300 nLL^{-1} 1-MCP	4.46	3.75	5.79	4.61	3.73	4.47
T_3	600 nLL^{-1} 1-MCP	4.26	3.82	6.00	4.73	3.71	4.50
T_4	900 nLL^{-1} 1-MCP	4.19	3.76	5.78	4.50	3.75	4.40
T_5	1200 nLL^{-1} 1-MCP	4.37	3.78	5.81	4.46	3.67	4.42
	CD at 5%	0.12	N/A	0.11	0.12	N/A	0.08
	SE(m)	0.04	0.07	0.03	0.04	0.04	0.02

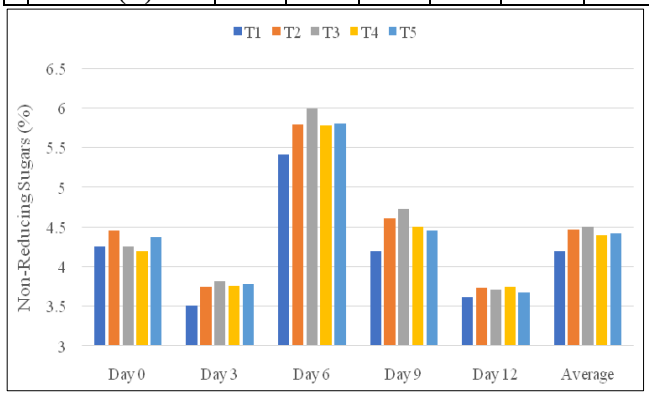

Fig 10: Effect of 1-MCP on non-reducing sugars (%) of guava fruits

Organoleptic parameters

From the study it can be seen that maximum (5.85) aroma was found in treatment T_3 (1-MCP 600 nLL^{-1}) and minimum (5.20) was observed in treatment T_1 (control). Maximum (5.83) texture was observed in treatment T_3 (1-MCP 600 nLL^{-1}) and minimum (5.13) was observed in treatment T_1 (control). Similarly maximum (5.93) flavour was observed in treatment T_3 (1-MCP 600 nLL^{-1}) and also minimum (5.33) was observed in treatment T_1 (control). Also, maximum (5.90) appearance was found in treatment T_3 (1-MCP 600 nLL^{-1}) and minimum (5.30) was found in treatment T_1 (control) (Table 13).

Overall acceptability was observed maximum (5.88) in treatment T_3 (1-MCP 600 nLL^{-1}) and minimum (5.24) was observed in treatment T_1 (control).

In this study, the successful application of 1-MCP treatment prevented the decrease in organic acids content in fruit, resulting in increased acidity. This indicates that 1-MCP effectively controlled the organic acids metabolism in the fruit (Liu *et al*., 2016) [42]. The presence of nitric oxide and the application of 1-MCP helps to preserve the sugars and acids in fruits, resulting in a reduced respiration rate. This preservation process ultimately contributes to maintaining the desired texture, aroma, and appearance in treated fruits compared to the controlled ones. Similar results were found in apple (Jonagold, Ampire and Mutsu) (Siddiq *et al*., 2014) [43] and in (Packham's Triumph) pear (Moya-Leon *et al*., 2006) [44].

Table 13: Effect of 1-MCP on organoleptic parameters of guava fruits

	Treatments	Organoleptic Parameters				
		Aroma	Texture	Flavour	Appearance	Overall acceptability
T_1	Control	5.20	5.13	5.33	5.30	5.24
T_2	300 nLL^{-1} 1-MCP	5.48	5.62	5.52	5.45	5.52
T_3	600 nLL^{-1} 1-MCP	5.85	5.83	5.93	5.90	5.88
T_4	900 nLL^{-1} 1-MCP	5.43	5.43	5.48	5.45	5.45
T_5	1200 nLL^{-1} 1-MCP	5.45	5.42	5.57	5.55	5.50

Conclusion

The current research demonstrates that various chemical treatments have a significant impact on the senescence and

quality of guava. The findings suggest that the application of different chemical substances effectively extends the senescence period and safeguards the overall quality of guava. Specifically, applying 1-MCP at a concentration of 600 nLL^{-1} yields better results compared to the control and other treatments. This treatment helps maintain several important attributes such as physiological weight loss (10.95%), maximum firmness (4.36 mg/cm^2), minimum decay (22%), minimal degradation of TSS (12.08 ºbrix), maximum brix-acid ratio (26.44), ascorbic acid content (167.64 mg/100gm), antioxidants (37.14%), flavonoid content (21.40 mg/100gm), total sugars (12.28%), and non-reducing sugars (4.50%). Also, the application of 1-MCP at a concentration of 600 nLL^{-1} preserves maximum reducing sugars (7.77%) and titratable acidity (0.52%). Furthermore, 1-MCP at 600 nLL^{-1} also maintains an overall acceptability rating (5.88) based on organoleptic parameters.

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