Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Synergistic Effect of Pre-harvest Nutrient Sprays and Photoselective Bagging on Quality Retention and Shelf life of Rainy Season Guava (Psidium guajava L.)

K. K. Mishra
kkmishrababbu@gmail.com
GOPAL NARAYAN SINGH UNIVERSITY
Sanjay Pathak
Acharya Narendra Deva University of Agriculture and Technology
Ankita Rao
GOPAL NARAYAN SINGH UNIVERSITY
Arun Shankar
GOPAL NARAYAN SINGH UNIVERSITY

Research Article

Keywords: Psidium guajava, fruit bagging, calcium chloride, potassium sulphate, postharvest quality, physiological loss in weight

Posted Date: November 24th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11558588/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Additional Declarations: No competing interests reported.

Abstract

Rainy season guava fruit is perishable and softens rapidly, loses weight quickly and has poor flavour under ambient conditions. This study evaluated pre-harvest foliar calcium chloride ($CaCl_2$, 2%) and potassium sulphate (K_2SO_4, 2%) alone and combined with perforated red, green, yellow and blue polythene bags applied 30 days before harvest on the postharvest quality of guava cv. Lucknow-49 stored at ambient temperature for 10 days. Sixteen treatments were laid out in a randomised block design with three replications over two rainy seasons (2015–16 and 2016–17). Total soluble solids (TSS), titratable acidity, ascorbic acid, total, reducing and non-reducing sugars, firmness, physiological loss in weight (PLW) and organoleptic quality were recorded at 2 day intervals. The combination of $CaCl_2$ + K_2SO_4 with blue polythene bags (T_{16}) gave the highest treatment means for TSS (15.16 and 13.43%), titratable acidity (0.53 and 0.55%), ascorbic acid (167.07 and 164.19 mg 100 g^{-1}), total sugars (14.00 and 13.63%), reducing sugars (8.55 and 8.32%) and organoleptic score (8.12 and 8.00; significant in 2015–16 only) and the lowest PLW (4.69 and 4.75%) in the two years, compared with 8.07 and 4.78% TSS, 120.37 and 118.22 mg 100 g^{-1} ascorbic acid and 13.80 and 14.29% PLW in untreated fruit. After 10 days, PLW of T_{16} fruit was 8.68–8.78% against 32.66–32.76% for the control. T_{16} was among the firmest treatments but did not differ consistently from several other treatments for firmness or non-reducing sugars. Because bagging only treatments were not included, the independent contribution of bagging cannot be separated from that of the nutrient sprays. Pre-harvest $CaCl_2$ + K_2SO_4 sprays with blue polythene bagging improved quality retention of rainy season Lucknow-49 guava during 10 days of ambient storage.

1. Introduction

Guava (*Psidium guajava* L.) is widely grown in tropical and subtropical regions and is valued for its vitamin C, dietary fibre, minerals and phenolic antioxidants (Chen et al., 2024; Ribeiro et al., 2020). India is among the leading guava producers, with an estimated 5.56 million tonnes in 2021–22 and 5.27 million tonnes in 2022–23 (AMIC-PJTSAU, 2024). The fruit is climacteric and highly perishable, so respiration, softening and weight loss proceed quickly after harvest (Chen et al., 2024). These problems are most severe in the rainy season, when high temperature and humidity accelerate ripening and senescence and favour insect and disease damage, producing fruit that is softer, less sweet and shorter lived than winter season fruit.

Pre-harvest mineral nutrition is a practical way to influence postharvest behaviour. Calcium is a structural component of the cell wall, where it cross links pectin and it contributes to membrane integrity and cell signalling (White and Broadley, 2003; Hepler, 2005). Adequate fruit calcium is therefore associated with firmer tissue and slower softening (Jaime-Guerrero et al., 2024). In red guava, pre-harvest $CaCl_2$ sprays raised fruit calcium and ascorbic acid content (Ribeiro et al., 2020). Potassium activates enzymes, supports photosynthate translocation and osmotic regulation, and is closely linked to sugar accumulation and flavour (Marschner, 2012). Foliar calcium plus potassium improved growth, yield and fruit quality of guava cv. L-49 in a recent field study (Tripathi et al., 2026), and pre-harvest calcium treatments have been tested for shelf life in guava (Goswami et al., 2008).

Pre-harvest fruit bagging is an eco-friendly practice that physically protects fruit from insects, pathogens and mechanical injury and alters light, temperature and humidity around the fruit (Sharma et al., 2014; Buthelezi et al., 2021). In guava, bagging has been reported to improve physical, biochemical and sensory attributes (Saxena et al., 2021; Kantwa et al., 2023; Zaid et al., 2026) and the effect varies with bag material and colour (Edirimanna et al., 2015; Rahman et al., 2018). Combining nutrient application with bagging has been examined for guava development and quality (Afroz et al., 2023).

However, the combined effect of foliar calcium and potassium with differently coloured polythene bags on the ambient storage behaviour of rainy season guava has not been examined for cv. Lucknow-49. This study therefore compared sixteen treatments, comprising $CaCl_2$ and K_2SO_4 sprays alone and in combination and the same sprays with red, green, yellow or blue perforated polythene bags, on TSS, acidity, ascorbic acid, sugars, firmness, PLW and sensory quality during 10 days of ambient storage over two rainy seasons.

2. Materials and Methods

2.1 Experimental site and plant material

The experiment was conducted in the rainy seasons of 2015-16 and 2016-17 at the Main Experimental Station and the Post-Harvest Technology Laboratory, College of Horticulture and Forestry, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India. Six year old, healthy and uniform guava trees of cv. Lucknow-49 planted at 5 m × 5 m and managed under standard orchard practices were used.

2.2 Experimental design and treatments

The experiment followed a randomised block design (RBD) with sixteen treatments and three replications; one tree was one experimental unit. Treatments were: T_1 control (no spray, no bag); T_2 $CaCl_2$ 2%; T_3 K_2SO_4 2%; T_4 $CaCl_2$ 2% + K_2SO_4 2%; T_5–T_8, $CaCl_2$ 2% + red, green, yellow and blue polythene bag, respectively; T_9–T_{12}, K_2SO_4 2% + red, green, yellow and blue bag; and T_{13}–T_{16}, $CaCl_2$ 2% + K_2SO_4 2% + red, green, yellow and blue bag.

2.3 Foliar sprays

Sprays were applied once, 30 days before harvest, with a hand-operated sprayer until runoff (approximately 10 L $tree^{-1}$). Tween-20 was added as surfactant. $CaCl_2$ and K_2SO_4 were dissolved separately in water before use. Control trees were unsprayed.

2.4 Fruit bagging

Immediately after spraying, uniform healthy fruits were enclosed individually in perforated coloured polythene bags (red, green, yellow and blue) tied with rubber bands at the fruit stalk and the bags were retained until harvest. Bag specifications were: film thickness 20µ gauge (anti fog polybag), bag size 20 cm × 30 cm, perforation diameter 127.3 mm and number of perforations per bag 6–7 (approximately 1% of the bag surface). Bags were obtained from Anukampa Polypackaging Industries, Talkatora Industrial Area, Lucknow, UP, India.

2.5 Harvest and storage

Fruits were harvested by hand at physiological maturity in the second week of August in both years in the morning to reduce field heat. They were washed in fresh water, sorted and graded to remove defective fruit. Five kilograms of fruit per treatment were packed in labelled, perforated polythene bags and held under ambient laboratory conditions with a mean temperature of 30°C and relative humidity of 84.9%. Observations were taken at 0, 2, 4, 6, 8 and 10 days of storage. Fruit weight was measured at each observation interval to calculate physiological loss in weight (PLW) relative to the initial fruit weight. Since no weight loss was recorded at the beginning of storage, PLW was considered 0% on day 0 and subsequent PLW values were reported from day 2 onwards.

2.6 Observations

Physiological loss in weight (PLW, %) was calculated as (AOAC, 2000):

$PLW\ (\%) = [(W_0 - W_t) / W_0] \times 100$

where W_0 is the initial fruit weight (g) and W_t is the fruit weight (g) on the observation day.

Firmness was measured with a Magness Taylor pressure tester fitted with a 5/16-inch (7.9 mm) plunger (D. Ballauf Manufacturing Company, Washington, D.C.) (Magness and Taylor, 1925) at two opposite sides of each fruit and expressed in kg cm^{-2}. TSS was measured in macerated pulp juice with a hand refractometer (0–32%), corrected to 20°C (Ranganna, 1986) and expressed as %.

Titratable acidity was determined by titrating a 5 mL aliquot of a filtrate made up to 50 mL from 5 g pulp against 0.1 N NaOH with phenolphthalein as indicator (Ruck, 1969) and expressed as % citric acid:

$Acidity\ (\%) = [Titre\ (mL) \times N \times 64 \times V] / [A \times W \times 1000] \times 100$

where N is the normality of NaOH, 64 is the equivalent weight of citric acid, V is the volume made up (mL), A is the aliquot taken (mL) and W is the weight of the sample (g).

Ascorbic acid was determined by titration against 2,6-dichlorophenol-indophenol in 3% metaphosphoric acid extract (Ranganna, 1986):

$Ascorbic\ acid\ (mg\ 100\ g^{-1}) = [Titre\ (mL) \times dye\ factor\ (mg\ mL^{-1}) \times V \times 100] / [A \times W]$

where V is the volume made up (mL), A is the aliquot taken (mL) and W is the sample weight (g).

Reducing and total sugars were determined by the Lane and Eynon (1923) method with Fehling's solution; non-reducing sugars were obtained from total sugars minus reducing sugars after inversion (expressed as sucrose, %), so that total sugars equal the sum of reducing and non-reducing sugars.

Organoleptic quality (peel colour, flesh colour, texture, taste and flavour) was scored by a panel of eight judges on a 9 point hedonic scale (Larmond, 1977): 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. The overall organoleptic score was calculated as the mean of the scores assigned to the five attributes by the eight judges.

2.7 Statistical analysis

Each year was analysed separately. The data were analysed by analysis of variance for an RBD with treatments and storage days as factors (Cochran and Cox, 1970). Standard errors of the mean (SEm±) and critical differences at P = 0.05 (CD) are given for treatments (T), storage days (D) and the interaction (T × D); N.S. means not significant.

3. Results and Discussion

Treatment means in the text are means over the six storage days (five for PLW); the effect of storage days is the mean of all treatments on that day. All values are from Tables 1–9. Treatment differences are called significant only where they exceed the CD in the table.

Table 1
Effect of pre-harvest nutrient sprays and bagging with different coloured polythene on total soluble solids (TSS, %) of rainy-season guava cv. Lucknow-49 during ambient storage.

Treatment	2015–16 (storage days)							2016–17 (storage days)						
	0	2	4	6	8	10	Mean	0	2	4	6	8	10	Mean
T_1	7.06	7.75	8.10	8.90	8.60	8.00	**8.07**	4.40	4.71	4.93	5.01	4.90	4.72	**4.78**
T_2	9.46	9.95	10.50	11.30	11.10	10.80	**10.52**	8.33	8.51	8.88	9.03	8.90	8.61	**8.71**
T_3	9.46	9.80	10.21	10.90	10.20	9.90	**10.08**	9.33	9.60	9.87	9.99	9.71	9.60	**9.68**
T_4	9.51	9.97	10.50	10.80	10.71	10.40	**10.32**	10.33	10.61	10.92	11.02	10.91	10.51	**10.72**
T_5	10.10	10.60	10.91	11.00	10.88	10.54	**10.67**	9.04	9.40	9.82	9.97	9.85	9.51	**9.60**
T_6	10.46	10.77	11.10	11.50	11.24	10.97	**11.01**	10.40	10.90	11.08	11.20	10.99	10.54	**10.85**
T_7	11.40	11.75	11.92	12.15	11.90	11.80	**11.82**	10.04	10.50	10.81	11.02	10.84	10.61	**10.64**
T_8	13.23	13.60	13.90	14.10	13.91	13.60	**13.72**	12.13	12.51	12.91	13.02	12.74	12.51	**12.64**
T_9	13.50	13.92	14.23	14.49	14.20	13.97	**14.05**	11.20	11.60	11.93	12.06	11.80	11.62	**11.70**
T_{10}	11.40	11.80	11.98	12.25	12.01	11.87	**11.89**	10.33	10.50	10.78	10.91	11.71	10.48	**10.79**
T_{11}	10.06	10.76	10.99	11.34	11.09	10.74	**10.83**	9.43	9.80	10.90	10.29	9.99	9.61	**10.00**
T_{12}	12.33	12.80	12.97	13.14	12.91	12.88	**12.84**	11.30	11.61	11.94	12.10	11.74	11.48	**11.70**
T_{13}	9.98	10.10	10.40	10.80	10.31	10.15	**10.29**	9.23	9.50	9.87	10.10	9.88	9.50	**9.68**
T_{14}	11.05	11.45	11.90	12.11	11.91	11.48	**11.65**	10.33	10.71	10.92	11.03	10.81	10.57	**10.73**
T_{15}	10.46	10.61	10.81	11.02	10.91	10.71	**10.75**	9.36	9.49	9.88	10.10	9.71	9.61	**9.69**
T_{16}	15.00	15.11	15.29	15.40	15.20	14.98	**15.16**	13.00	13.41	13.61	13.78	13.51	13.27	**13.43**
Mean	**10.90**	**11.30**	**11.61**	**11.95**	**11.69**	**11.42**	**11.48**	**9.89**	**10.21**	**10.57**	**10.66**	**10.50**	**10.17**	**10.33**
SEm± (T / D / T×D)	**0.16 / 0.30 / 0.67**							**0.16 / 0.29 / 0.65**						
CD (P = 0.05) (T / D / T×D)	**0.47 / 0.84 / N.S.**							**0.45 / 0.81 / N.S.**						

T = treatments, D = storage days, N.S. = not significant.

3.1 Total soluble solids

Treatments differed significantly in TSS in both years (CD for treatments 0.47 and 0.45%; Table 1). T_{16} had the highest mean (15.16 and 13.43%), whereas the control had the lowest (8.07 and 4.78%). In 2015–16, T_{16} exceeded T_9 (14.05%) and T_8 (13.72%) by more than the CD. Within the $CaCl_2$ + K_2SO_4 series, T_{16} (blue) exceeded T_{13}, T_{14} and T_{15} (10.29–11.65% in 2015–16; 9.68–10.73% in 2016–17) and the unbagged T_4 (10.32 and 10.72%). Storage days also had a significant effect (CD for days 0.84 and 0.81%). Mean TSS rose from 10.90 to 11.95% between day 0 and day 6 and fell to 11.42% at day 10 in 2015–16 (9.89, 10.66 and 10.17% in 2016–17). T_{16} peaked at 15.40 and 13.78% on day 6. The treatment × day interaction was not significant.

The rise during storage is consistent with hydrolysis of starch and other polysaccharides, and the later decline with use of sugars in respiration, as described for guava ripening (Chen et al., 2024). The higher TSS of T_{16} agrees with the better carbohydrate status expected from adequate potassium (Marschner, 2012) and with the improved biochemical quality of bagged L-49 fruit reported by Zaid et al. (2026) and of nutrient-sprayed L-49 trees by Tripathi et al. (2026).

3.2 Titratable acidity

Acidity declined with storage in all treatments (Table 2). Mean acidity over days fell from 0.58 to 0.31% in 2015–16 and from 0.56 to 0.28% in 2016–17, i.e. by about 47% and 50% (CD for days 0.02 and 0.027%). T_{16} retained the highest mean acidity (0.53 and 0.55%) against 0.40 and 0.37% in the control, and its day-10 values (0.41 and 0.40%) were the highest in both years. The treatment × day interaction was significant in 2015–16 but not in 2016–17.

Table 2
Effect of pre-harvest nutrient sprays and bagging with different coloured polythene on titratable acidity (%) of rainy-season guava cv. Lucknow-49 during ambient storage.

Treatment	2015–16 (storage days)							2016–17 (storage days)						
	0	2	4	6	8	10	Mean	0	2	4	6	8	10	Mean
T_1	0.54	0.48	0.42	0.38	0.31	0.28	**0.40**	0.52	0.47	0.40	0.34	0.28	0.21	**0.37**
T_2	0.54	0.53	0.51	0.48	0.45	0.39	**0.48**	0.53	0.51	0.47	0.41	0.38	0.34	**0.44**
T_3	0.56	0.53	0.48	0.44	0.40	0.36	**0.46**	0.55	0.50	0.44	0.40	0.35	0.31	**0.43**
T_4	0.55	0.54	0.46	0.39	0.35	0.31	**0.43**	0.54	0.50	0.45	0.41	0.35	0.31	**0.43**
T_5	0.56	0.50	0.45	0.40	0.36	0.30	**0.43**	0.54	0.51	0.44	0.38	0.31	0.28	**0.41**
T_6	0.61	0.56	0.52	0.47	0.42	0.35	**0.49**	0.58	0.54	0.48	0.41	0.34	0.29	**0.44**
T_7	0.56	0.52	0.51	0.42	0.35	0.29	**0.44**	0.53	0.47	0.41	0.38	0.31	0.26	**0.39**
T_8	0.58	0.54	0.50	0.48	0.41	0.35	**0.48**	0.56	0.51	0.47	0.40	0.34	0.30	**0.43**
T_9	0.51	0.56	0.48	0.40	0.34	0.29	**0.43**	0.55	0.50	0.45	0.41	0.31	0.28	**0.42**
T_{10}	0.56	0.51	0.45	0.41	0.36	0.30	**0.43**	0.54	0.49	0.41	0.37	0.31	0.26	**0.40**
T_{11}	0.63	0.57	0.51	0.45	0.38	0.27	**0.47**	0.60	0.55	0.50	0.45	0.37	0.27	**0.46**
T_{12}	0.62	0.53	0.45	0.40	0.31	0.23	**0.42**	0.58	0.55	0.48	0.39	0.30	0.21	**0.42**
T_{13}	0.60	0.53	0.44	0.37	0.29	0.21	**0.41**	0.57	0.50	0.40	0.31	0.28	0.20	**0.38**
T_{14}	0.58	0.50	0.45	0.41	0.35	0.29	**0.43**	0.57	0.48	0.40	0.34	0.27	0.21	**0.38**
T_{15}	0.54	0.49	0.45	0.40	0.36	0.31	**0.43**	0.55	0.50	0.47	0.40	0.33	0.30	**0.43**
T_{16}	0.67	0.61	0.52	0.48	0.46	0.41	**0.53**	0.69	0.63	0.58	0.52	0.47	0.40	**0.55**
Mean	**0.58**	**0.53**	**0.48**	**0.42**	**0.37**	**0.31**	**0.45**	**0.56**	**0.51**	**0.45**	**0.40**	**0.33**	**0.28**	**0.42**
SEm± (T / D / T×D)	**0.005 / 0.01 / 0.02**							**0.005 / 0.009 / 0.02**						
CD (P = 0.05) (T / D / T×D)	**0.015 / 0.02 / 0.06**							**0.015 / 0.027 / N.S.**						
T = treatments, D = storage days, N.S. = not significant.														

Slower loss of acid in treated fruit indicates slower use of organic acids as respiratory substrates, i.e. delayed ripening and senescence (Saxena et al., 2021; Kantwa et al., 2023). This agrees with the greater calcium-mediated stability of cell membranes noted in calcium-treated fruit (Jaime-Guerrero et al., 2024).

3.3 Ascorbic acid

Ascorbic acid differed significantly among treatments (CD 0.39 mg 100 g^{-1}; Table 3). T_{16} had the highest mean (167.07 and 164.19 mg 100 g^{-1}), 38.8–38.9% above the control (120.37 and 118.22 mg 100 g^{-1}), and the highest peak (197.11 and 195.28 mg 100 g^{-1} on day 6). Blue bags gave higher ascorbic acid than the unbagged spray of the same nutrient: T_8 150.76 vs T_2 131.01, T_{12} 154.08 vs T_3 135.48 and T_{16} 167.07 vs T_4 143.46 mg 100 g^{-1} in 2015–16 (CD 0.39), and the same pattern held in 2016–17; red, green and yellow bags did not raise ascorbic acid above T_4 in the $CaCl_2$ + K_2SO_4 series (T_{13}–T_{15}, 141.11–142.42 vs 143.46 mg 100 g^{-1} in 2015–16). Storage days had a strong effect (CD 0.70): mean values were stable up to day 6 (164.27 to 167.26 mg 100 g^{-1} in 2015–16) and then dropped to 110.22 on day 8 and 70.31 mg 100 g^{-1} on day 10; the 2016–17 pattern was similar (160.90, 164.20, 104.72 and 64.19 mg 100 g^{-1} on days 0, 6, 8 and 10). T_{16} still held 90.44 and 84.44 mg 100 g^{-1} on day 10, against 42.00 and 40.41 mg 100 g^{-1} in the control.

Table 3
Effect of pre-harvest nutrient sprays and bagging with different coloured polythene on ascorbic acid (mg 100 g⁻¹) of rainy-season guava cv. Lucknow-49 durin ambient storage.

Treatment	2015–16 (storage days)							2016–17 (storage days)						
	0	2	4	6	8	10	Mean	0	2	4	6	8	10	Mean
T_1	145.00	146.10	147.40	147.71	94.00	42.00	**120.37**	143.91	144.46	144.90	145.61	90.00	40.41	**118.22**
T_2	153.44	154.10	156.00	158.10	112.00	52.44	**131.01**	152.84	153.56	154.40	156.74	108.00	49.44	**129.16**
T_3	156.81	157.21	158.40	159.44	100.00	81.00	**135.48**	156.00	157.10	158.31	159.41	98.41	78.10	**134.56**
T_4	160.71	161.10	162.36	164.44	120.00	92.14	**143.46**	157.10	158.40	159.44	160.84	108.20	69.61	**135.60**
T_5	161.44	162.94	164.00	164.86	114.12	85.10	**142.08**	155.39	156.41	157.91	159.09	111.28	72.80	**135.48**
T_6	153.41	154.12	155.80	157.24	120.11	64.75	**134.24**	151.89	152.78	153.80	155.00	109.14	60.00	**130.44**
T_7	156.46	157.12	158.46	159.94	118.00	70.84	**136.80**	151.14	152.40	153.44	154.74	110.04	68.78	**131.76**
T_8	177.00	178.22	179.46	180.12	110.09	79.64	**150.76**	175.01	176.12	177.87	178.39	100.40	66.40	**145.70**
T_9	159.61	160.62	160.94	161.90	102.10	64.40	**134.93**	150.21	151.23	152.40	153.80	98.44	62.00	**128.01**
T_{10}	155.21	156.14	156.89	158.00	99.94	71.71	**132.98**	149.40	150.20	151.37	152.99	102.04	68.71	**129.12**
T_{11}	164.30	164.84	165.80	166.44	111.70	65.78	**139.81**	157.43	158.71	159.38	160.10	101.20	66.12	**133.82**
T_{12}	183.23	183.80	184.74	185.40	118.80	68.51	**154.08**	182.00	183.14	184.23	185.58	107.44	58.98	**150.23**
T_{13}	169.31	169.71	170.23	171.41	109.00	64.84	**142.42**	167.00	168.44	169.74	170.24	108.14	60.80	**140.73**
T_{14}	171.00	171.44	172.56	173.58	104.44	60.67	**142.28**	172.06	173.00	174.48	175.05	99.72	55.18	**141.58**
T_{15}	167.40	168.84	169.20	170.44	100.10	70.70	**141.11**	161.10	162.45	163.35	164.29	97.74	65.29	**135.70**
T_{16}	194.00	195.00	196.71	197.11	129.14	90.44	**167.07**	192.00	193.40	194.61	195.28	125.40	84.44	**164.19**
Mean	**164.27**	**165.08**	**166.18**	**167.26**	**110.22**	**70.31**	**140.55**	**160.90**	**161.99**	**163.10**	**164.20**	**104.72**	**64.19**	**136.52**
SEm± (T / D / T×D)	**0.14 / 0.25 / 0.56**							**0.14 / 0.25 / 0.56**						
CD (P = 0.05) (T / D / T×D)	**0.39 / 0.70 / 1.58**							**0.39 / 0.70 / 1.57**						

T = treatments, D = storage days, N.S. = not significant.

The sharp decline after day 6 reflects oxidative degradation during over-ripening. Calcium-stabilised membranes may reduce oxidative loss (Jaime-Guerrero et al., 2024). The peak in T_{16} (about 197 mg 100 g⁻¹) is of the same magnitude as the value obtained with 1% pre-harvest $CaCl_2$ in red guava (196.5 mg 100 g⁻¹; Ribeiro et al., 2020), although cultivar and season differ.

3.4 Total sugars

Total sugars were highest in T_{16} in 2016–17 (13.63%) and, in 2015–16, in T_{16} (14.00%) and T_9 (13.95%), which did not differ (CD 0.47 and 0.45%; Table 4). The control had the lowest means (8.12 and 7.95%). Total sugars peaked on day 6 in all treatments, with a day mean of 14.43 and 14.46% against 8.92 and 8.21% at day 0 and 11.31 and 10.33% at day 10 (CD for days 0.84 and 0.81%); T_{16} reached 17.44 and 16.91% on day 6.

Table 4
Effect of pre-harvest nutrient sprays and bagging with different coloured polythene on total sugars (%) of rainy-season guava cv. Lucknow-49 during ambient storage.

Treatment	2015–16 (storage days)							2016–17 (storage days)						
	0	2	4	6	8	10	Mean	0	2	4	6	8	10	Mean
T_1	5.14	7.24	8.60	9.51	8.59	9.61	**8.12**	4.98	6.40	8.79	9.61	9.80	8.10	**7.95**
T_2	7.79	9.34	10.99	11.30	9.96	9.44	**9.80**	7.19†	10.21	12.75	13.78	12.28	10.33	**11.09**
T_3	7.73	9.11	9.92	11.12	10.00	9.13	**9.50**	7.09†	9.11	11.30	13.15	10.94	8.30	**9.98**
T_4	8.75	10.57	11.34	12.42	11.20	10.53	**10.80**	7.46	10.10	11.93	13.26	11.71	9.61	**10.68**
T_5	9.53	10.42	11.81	14.21	13.11	12.49	**11.93**	8.88	11.52	13.09	15.26	13.31	10.95	**12.17**
T_6	10.00	10.95	12.67	15.05	13.62	12.21	**12.42**	7.69	10.29	12.20	14.74	13.48	11.05	**11.58**
T_7	10.23	11.92	14.59	16.10	15.10	13.63	**13.60**	10.07	12.61	14.90	16.19	13.81	11.59	**13.20**
T_8	8.10	9.60	11.10	13.49	11.20	9.75	**10.54**	7.92	9.65	11.90	14.21	13.09	10.82	**11.27**
T_9	10.41	12.64	15.16	17.25	15.35	12.91	**13.95**	10.15	12.23	14.61	16.42	13.29	10.81	**12.92**
T_{10}	9.95	12.16	14.69	17.20	15.09	12.68	**13.63**	8.71	11.15	13.75	15.17	13.75	10.89	**12.24**
T_{11}	8.74	10.44	12.80	14.97	13.60	11.39	**11.99**	8.39	10.47	13.04	15.38	13.24	10.80	**11.89**
T_{12}	10.81	12.86	14.48	15.94	14.71	12.54	**13.56**	9.31	11.02	13.48	15.13	12.57	10.51	**12.00**
T_{13}	9.00	11.52	13.69	15.21	13.97	10.59	**12.33**	7.84	10.68	12.89	14.06	11.07	9.62	**11.03**
T_{14}	8.01	9.69	11.54	14.72	12.20	11.02	**11.20**	8.49	9.49	12.81	14.16	12.67	10.72	**11.39**
T_{15}	7.62	10.37	12.70	14.98	12.79	10.54	**11.50**	6.49	9.26	11.47	13.83	11.72	9.19	**10.33**
T_{16}	10.91	12.41	15.54	17.44	15.21	12.51	**14.00**	10.77	12.84	14.45	16.91	14.83	12.00	**13.63**
Mean	**8.92**	**10.70**	**12.60**	**14.43**	**12.86**	**11.31**	**11.80**	**8.21**	**10.44**	**12.71**	**14.45**	**12.59**	**10.33**	**11.46**
SEm± (T / D / T×D)	**0.16 / 0.30 / 0.67**							**0.16 / 0.29 / 0.65**						
CD (P = 0.05) (T / D / T×D)	**0.47 / 0.84 / N.S.**							**0.45 / 0.81 / N.S.**						

T = treatments, D = storage days, N.S. = not significant. † Total sugars differ from reducing + non-reducing sugars (Tables 5 and 6) by more than 0.05 percentage points; in all other cells they agree within 0.05.

The increase during ripening reflects starch and pectin conversion to sugars, and potassium supports sugar synthesis and transport into the fruit (Marschner, 2012). Higher sugar accumulation after calcium and potassium sprays in guava has also been reported for L-49 (Tripathi et al., 2026).

3.5 Reducing and non-reducing sugars

Reducing sugars (Table 5) were highest in T_{16} (8.55 and 8.32%) and lowest in the control (4.11 and 3.55%). In 2015–16 T_{16} was at par with T_{12} (8.36%) and higher than all other treatments (CD 0.26%); in 2016–17 T_{16} was higher than all others (next highest T_9, 8.00%; CD 0.24%). Day means peaked on day 6 (7.31 and 6.71%). Non-reducing sugars (Table 6) increased to a day-6 peak (7.12 and 7.75%) and then declined (4.59 and 4.26% on day 10; CD for days 0.37 and 0.39%). T_{16} did not have the highest non-reducing sugar mean (5.46 and 5.31%); the highest were T_{10} (5.90%), T_{15} (5.89%) and T_9 (5.83%) in 2015–16 and T_6 (5.68%) in 2016–17, so the advantage of T_{16} in total sugars comes mainly from reducing sugars. Total sugars (Table 4) agreed with the sum of reducing and non-reducing sugars (Tables 5 and 6) within 0.05 percentage points in 190 of 192 treatment × day × year cells; the two exceptions (T_2 and T_3 on day 0 in 2016–17) are marked † in Table 4.

Table 5
Effect of pre-harvest nutrient sprays and bagging with different coloured polythene on reducing sugars (%) of rainy-season guava cv. Lucknow-49 during ambient storage.

Treatment	2015–16 (storage days)							2016–17 (storage days)						
	0	2	4	6	8	10	Mean	0	2	4	6	8	10	Mean
T_1	3.09	4.14	4.40	4.60	4.30	4.10	**4.11**	3.00	3.40	3.81	4.00	3.70	3.39	**3.55**
T_2	5.57	5.90	5.99	6.11	5.96	5.71	**5.87**	5.57	5.81	6.14	6.34	6.16	6.00	**6.00**
T_3	5.31	5.50	5.89	6.21	6.00	5.72	**5.77**	4.31	4.50	4.91	5.15	4.80	4.30	**4.66**
T_4	6.40	6.78	6.93	7.10	6.81	6.61	**6.77**	5.19	5.50	5.95	6.08	5.71	5.44	**5.64**
T_5	7.12	7.43	7.81	8.21	8.00	7.71	**7.71**	6.56	6.81	7.00	7.16	7.02	6.81	**6.89**
T_6	7.60	7.97	8.23	8.81	8.41	8.11	**8.19**	5.35	5.81	6.01	6.36	6.04	5.81	**5.90**
T_7	7.40	7.81	7.97	8.10	7.91	7.72	**7.82**	7.26	7.53	7.93	8.29	7.90	7.34	**7.71**
T_8	5.39	5.62	5.92	6.25	6.01	5.75	**5.82**	5.25	5.65	5.80	6.00	5.91	5.62	**5.71**
T_9	7.89	8.12	8.26	8.44	8.14	7.91	**8.13**	7.68	7.99	8.21	8.61	8.00	7.50	**8.00**
T_{10}	7.25	7.65	7.98	8.21	7.89	7.40	**7.73**	6.01	6.65	6.98	7.10	6.88	6.51	**6.69**
T_{11}	6.11	6.44	6.88	7.08	6.92	6.39	**6.64**	5.80	6.06	6.86	7.24	7.00	6.70	**6.61**
T_{12}	7.80	8.09	8.50	8.94	8.61	8.21	**8.36**	6.39	6.62	6.97	7.18	6.76	6.51	**6.74**
T_{13}	6.20	6.71	6.98	7.21	6.96	6.40	**6.74**	5.12	5.54	5.94	6.14	5.89	5.64	**5.71**
T_{14}	5.48	5.78	6.10	6.81	6.20	5.91	**6.05**	6.00	5.52	6.90	7.05	6.89	6.48	**6.47**
T_{15}	5.10	5.46	5.81	6.00	5.83	5.44	**5.61**	4.07	4.69	4.99	5.64	5.24	5.01	**4.94**
T_{16}	8.00	8.41	8.74	8.93	8.70	8.51	**8.55**	7.96	8.14	8.64	8.94	8.24	8.00	**8.32**
Mean	**6.36**	**6.74**	**7.02**	**7.31**	**7.04**	**6.73**	**6.87**	**5.72**	**6.01**	**6.44**	**6.71**	**6.38**	**6.07**	**6.22**
SEm± (T / D / T×D)	**0.09 / 0.17 / 0.38**							**0.08 / 0.15 / 0.34**						
CD (P = 0.05) (T / D / T×D)	**0.26 / 0.47 / N.S.**							**0.24 / 0.43 / N.S.**						

T = treatments, D = storage days, N.S. = not significant.

Table 6
Effect of pre-harvest nutrient sprays and bagging with different coloured polythene on non-reducing sugars (%) of rainy-season guava cv. Lucknow-49 during ambient storage.

Treatment	2015–16 (storage days)							2016–17 (storage days)						
	0	2	4	6	8	10	Mean	0	2	4	6	8	10	Mean
T_1	2.05	3.10	4.20	4.91	4.29	5.51	**4.01**	1.98	3.00	4.98	5.61	6.10	4.71	**4.40**
T_2	2.22	3.44	5.00	5.19	4.00	3.73	**3.93**	2.12	4.40	6.61	7.44	6.12	4.33	**5.17**
T_3	2.42	3.61	4.03	4.91	4.00	3.41	**3.73**	2.30	4.61	6.39	8.00	6.14	4.00	**5.24**
T_4	2.35	3.79	4.41	5.32	4.39	3.92	**4.03**	2.27	4.60	5.98	7.18	6.00	4.17	**5.03**
T_5	2.41	2.99	4.00	6.00	5.11	4.78	**4.22**	2.32	4.71	6.09	8.10	6.29	4.14	**5.28**
T_6	2.40	2.98	4.44	6.24	5.21	4.10	**4.23**	2.34	4.48	6.19	8.38	7.44	5.24	**5.68**
T_7	2.83	4.11	6.62	8.00	7.19	5.91	**5.78**	2.81	5.08	6.97	7.90	5.91	4.25	**5.49**
T_8	2.71	3.98	5.18	7.24	5.19	4.00	**4.72**	2.67	4.00	6.10	8.21	7.18	5.20	**5.56**
T_9	2.52	4.52	6.90	8.81	7.21	5.00	**5.83**	2.47	4.24	6.40	7.81	5.29	3.31	**4.92**
T_{10}	2.70	4.51	6.71	8.99	7.20	5.28	**5.90**	2.70	4.50	6.77	8.07	6.87	4.38	**5.55**
T_{11}	2.63	4.00	5.92	7.89	6.68	5.00	**5.35**	2.59	4.41	6.18	8.14	6.24	4.10	**5.28**
T_{12}	3.01	4.77	5.98	7.00	6.10	4.33	**5.20**	2.92	4.40	6.51	7.95	5.81	4.00	**5.27**
T_{13}	2.80	4.81	6.71	8.00	7.01	4.19	**5.59**	2.72	5.14	6.95	7.92	5.18	3.98	**5.32**
T_{14}	2.53	3.91	5.44	7.91	6.00	5.11	**5.15**	2.49	3.97	5.91	7.11	5.78	4.24	**4.92**
T_{15}	2.52	4.91	6.89	8.98	6.96	5.10	**5.89**	2.42	4.57	6.48	8.19	6.48	4.18	**5.39**
T_{16}	2.91	4.00	6.80	8.51	6.51	4.00	**5.46**	2.81	4.70	5.81	7.97	6.59	4.00	**5.31**
Mean	**2.56**	**3.96**	**5.58**	**7.12**	**5.82**	**4.59**	**4.94**	**2.50**	**4.43**	**6.27**	**7.75**	**6.21**	**4.26**	**5.24**
SEm± (T / D / T×D)	**0.07 / 0.13 / 0.30**							**0.07 / 0.14 / 0.31**						
CD (P = 0.05) (T / D / T×D)	**0.20 / 0.37 / 0.83**							**0.21 / 0.39 / 0.87**						
T = treatments, D = storage days, N.S. = not significant.														

The rise in reducing sugars followed by a fall, and the sucrose peak followed by hydrolysis, are typical of climacteric ripening and subsequent respiratory use of sugars (Saxena et al., 2021; Kantwa et al., 2023).

3.6 Fruit firmness

Firmness declined with storage in all treatments (Table 7); the day mean fell from 9.59 to 4.68 kg cm⁻² (51%) in 2015–16 and from 9.76 to 6.15 kg cm⁻² (37%) in 2016–17 (CD for days 0.48 and 0.49). Treatment effects were significant (CD 0.27 and 0.29 kg cm⁻²) but T_{16} was not consistently the firmest. In 2015–16 the highest means were T_{14} (8.29) and T_{16} (8.18 kg cm⁻²), which did not differ, against 6.74 in the control; both had 6.04 kg cm⁻² on day 10, versus 4.23 in the control. In 2016–17 T_{11} (8.45) and T_{12} (8.42) had the highest means and T_{16} had 8.08 kg cm⁻², against 6.41 in the control. T_{16} had the highest initial firmness in both years (10.67 and 10.74 kg cm⁻²).

Table 7
Effect of pre-harvest nutrient sprays and bagging with different coloured polythene on fruit firmness (kg cm⁻²) of rainy-season guava cv. Lucknow-49 during ambient storage.

Treatment	2015–16 (storage days)							2016–17 (storage days)						
	0	2	4	6	8	10	Mean	0	2	4	6	8	10	Mean
T_1	8.57	7.81	7.07	6.79	5.99	4.23	**6.74**	8.61	7.74	6.44	6.24	5.45	4.00	**6.41**
T_2	9.14	8.71	7.87	6.55	6.03	5.12	**7.23**	9.45	8.90	8.10	7.66	7.15	6.58	**7.97**
T_3	9.18	8.91	6.78	5.79	4.73	4.42	**6.64**	9.27	8.70	8.13	7.46	7.01	6.44	**7.84**
T_4	9.22	8.42	7.07	6.12	5.14	4.33	**6.72**	9.48	8.79	8.47	7.09	6.37	6.00	**7.70**
T_5	9.44	8.31	7.05	6.02	5.54	4.98	**6.89**	9.70	8.18	7.67	7.12	6.56	6.08	**7.55**
T_6	9.46	8.41	7.19	6.30	5.90	4.13	**6.90**	9.65	9.01	8.39	7.89	7.04	6.48	**8.08**
T_7	9.44	8.44	7.63	5.99	5.89	4.39	**6.96**	9.72	9.14	8.62	8.09	7.46	6.76	**8.30**
T_8	9.40	8.50	7.00	6.53	5.07	4.40	**6.82**	9.55	9.03	8.47	7.91	7.10	6.37	**8.07**
T_9	9.56	8.51	7.23	6.33	5.47	4.01	**6.85**	9.80	9.14	8.57	7.97	7.21	6.63	**8.22**
T_{10}	9.54	8.21	7.12	6.04	5.34	4.70	**6.83**	9.67	9.07	8.39	7.92	7.22	6.66	**8.16**
T_{11}	9.94	8.31	7.01	6.00	5.23	4.01	**6.75**	10.11	9.49	8.89	8.14	7.37	6.72	**8.45**
T_{12}	10.13	8.92	7.98	6.44	5.11	4.50	**7.18**	10.20	9.53	8.79	8.06	7.33	6.58	**8.42**
T_{13}	9.90	8.89	7.79	6.12	5.21	4.44	**7.06**	10.05	9.28	8.62	7.05	6.57	6.02	**7.93**
T_{14}	10.11	9.23	9.00	8.21	7.13	6.04	**8.29**	10.18	9.20	8.92	7.94	7.11	6.00	**8.23**
T_{15}	9.80	9.21	8.23	7.99	6.44	5.14	**7.80**	10.00	9.42	8.28	7.91	6.40	5.04	**7.84**
T_{16}	10.67	9.71	8.54	7.63	6.51	6.04	**8.18**	10.74	9.44	8.22	7.77	6.36	5.96	**8.08**
Mean	**9.59**	**8.66**	**7.54**	**6.55**	**5.67**	**4.68**	**7.11**	**9.76**	**9.00**	**8.31**	**7.64**	**6.86**	**6.15**	**7.95**
SEm± (T / D / T×D)	**0.09 / 0.17 / 0.39**							**0.10 / 0.18 / 0.38**						
CD (P = 0.05) (T / D / T×D)	**0.27 / 0.48 / N.S.**							**0.29 / 0.49 / N.S.**						
T = treatments, D = storage days, N.S. = not significant.														

Firmness retention by pre-harvest calcium is explained by calcium pectate formation in the cell wall and middle lamella, which limits softening (White and Broadley, 2003; Jaime-Guerrero et al., 2024). The additional firmness of some bagged treatments may reflect a slower ripening rate in the bag microenvironment (Sharma et al., 2014).

3.7 Physiological loss in weight

PLW increased with storage (Table 8), from a day mean of 1.50 and 1.60% on day 2 to 11.18 and 11.28% on day 10 (CD for days 0.45 and 0.58); the treatment × day interaction was significant. T_{16} had the lowest PLW mean (4.69 and 4.75%) against 13.80 and 14.29% in the control, a reduction of about 66–67%. On day 10 the control lost 32.66 and 32.76% of its weight and T_{16} 8.68 and 8.78%. Most of the benefit came from the nutrient sprays: all treated fruit other than T_{16} had means of 4.98–5.96% in 2015–16. The unbagged sprays T_2, T_3 and T_4 (5.25–5.46%) were within 0.35 percentage points of the blue-bag treatments T_8 (5.11%) and T_{12} (5.27%), whereas T_{16} was lower than T_4 by 0.77 percentage points (CD 0.25). T_{14} (4.99%) and T_{15} (4.98%) were the next lowest.

Table 8
Effect of pre-harvest nutrient sprays and bagging with different coloured polythene on physiological loss in weight (PLW, %) of rainy-season guava cv. Lucknow-49 during ambient storage.

Treatment	2015–16 (storage days)						2016–17 (storage days)					
	2	**4**	**6**	**8**	**10**	**Mean**	**2**	**4**	**6**	**8**	**10**	**Mean**
T_1	3.94	6.94	8.12	17.32	32.66	**13.80**	4.00	6.99	10.28	17.43	32.76	**14.29**
T_2	1.46	2.79	4.74	7.63	9.96	**5.32**	1.75	2.90	4.79	7.68	10.00	**5.42**
T_3	1.31	2.91	5.96	7.14	8.93	**5.25**	1.48	2.95	6.03	7.24	8.99	**5.34**
T_4	1.33	3.26	5.34	7.12	10.23	**5.46**	1.46	3.33	5.44	7.23	10.45	**5.58**
T_5	1.21	3.93	5.39	8.93	10.36	**5.96**	1.29	3.98	5.46	8.99	10.47	**6.04**
T_6	1.26	3.46	5.66	8.84	10.19	**5.88**	1.33	3.51	5.71	8.92	10.34	**5.96**
T_7	1.23	3.97	4.98	8.11	10.98	**5.85**	1.34	4.09	5.09	8.22	11.05	**5.96**
T_8	1.27	3.84	4.45	6.84	9.16	**5.11**	1.37	3.91	4.51	6.91	9.31	**5.20**
T_9	1.46	3.55	5.13	7.26	9.91	**5.46**	1.57	3.65	5.23	7.36	9.98	**5.56**
T_{10}	1.48	3.34	5.99	6.89	9.38	**5.42**	1.54	3.43	6.10	6.94	9.45	**5.49**
T_{11}	1.41	3.93	5.23	7.84	10.77	**5.84**	1.47	4.00	5.33	7.95	10.87	**5.92**
T_{12}	1.99	3.92	4.83	6.31	9.29	**5.27**	2.13	3.99	4.93	6.43	9.42	**5.38**
T_{13}	1.02	3.09	5.44	7.03	10.02	**5.32**	1.02	3.19	5.64	7.19	10.10	**5.43**
T_{14}	1.28	3.23	4.23	6.93	9.23	**4.99**	1.37	3.33	4.36	7.03	9.33	**5.08**
T_{15}	1.25	3.46	4.98	6.11	9.09	**4.98**	1.35	3.51	5.08	6.13	9.19	**5.05**
T_{16}	1.12	2.27	4.37	6.99	8.68	**4.69**	1.19	2.34	4.42	7.00	8.78	**4.75**
Mean	**1.50**	**3.62**	**5.30**	**7.96**	**11.18**	5.91	**1.60**	**3.69**	**5.53**	**8.04**	**11.28**	**6.03**
SEm± (T / D / T×D)	**0.09 / 0.16 / 0.36**						**0.10 / 0.20 / 0.41**					
CD (P = 0.05) (T / D / T×D)	**0.25 / 0.45 / 1.02**						**0.29 / 0.58 / 1.16**					

T = treatments, D = storage days, N.S. = not significant. PLW at day 0 is 0.00% by definition for all treatments and is therefore not tabulated.

Table 9
Effect of pre-harvest nutrient sprays and bagging with different coloured polythene on organoleptic quality (9-point hedonic scale) of rainy-season guava cv. Lucknow-49 during ambient storage.

Treatment	2015–16 (storage days)							2016–17 (storage days)						
	0	2	4	6	8	10	Mean	0	2	4	6	8	10	Mean
T_1	5.46	6.21	6.04	5.74	5.01	4.44	**5.48**	5.40	5.98	5.88	5.14	4.60	4.00	**5.17**
T_2	6.42	8.44	8.34	7.91	7.00	5.14	**7.21**	6.21	8.31	8.27	8.00	6.19	5.00	**7.00**
T_3	5.88	7.96	7.77	7.40	6.90	5.44	**6.89**	6.14	7.86	7.72	7.14	6.00	5.42	**6.71**
T_4	7.93	8.09	7.97	7.81	7.02	5.98	**7.47**	7.89	8.09	7.86	7.24	6.10	5.87	**7.18**
T_5	7.72	8.21	8.11	7.90	7.11	5.90	**7.49**	7.69	8.11	7.92	7.31	6.71	5.39	**7.19**
T_6	7.78	8.31	8.20	7.97	6.98	5.81	**7.51**	7.75	8.14	7.98	7.14	6.44	5.40	**7.14**
T_7	7.60	8.12	8.02	7.89	6.64	5.71	**7.33**	7.58	8.01	7.93	7.24	6.09	5.61	**7.08**
T_8	6.98	8.71	8.64	8.21	6.44	5.62	**7.43**	6.78	8.68	8.44	7.98	6.10	5.30	**7.21**
T_9	7.90	8.21	8.04	7.88	6.14	5.47	**7.27**	7.88	8.40	7.92	7.44	5.87	5.34	**7.14**
T_{10}	7.94	8.32	8.22	7.99	6.00	5.42	**7.32**	7.90	8.51	8.00	7.71	5.74	5.68	**7.26**
T_{11}	7.30	8.62	8.47	8.09	7.10	5.61	**7.53**	7.24	8.71	8.40	8.00	6.91	5.55	**7.47**
T_{12}	7.21	8.35	8.30	7.92	6.92	5.37	**7.35**	7.18	8.75	8.51	8.02	6.14	5.31	**7.32**
T_{13}	8.14	8.78	8.71	8.39	6.12	5.44	**7.60**	8.04	8.52	8.30	7.91	5.81	5.34	**7.32**
T_{14}	8.15	8.54	8.48	8.00	6.13	5.20	**7.42**	8.04	8.72	8.29	7.92	5.91	5.09	**7.33**
T_{15}	7.98	8.48	8.44	8.14	6.34	5.44	**7.47**	7.79	8.90	8.62	8.11	6.29	5.40	**7.52**
T_{16}	8.84	9.02	8.98	8.25	7.30	6.34	**8.12**	8.78	9.01	8.91	8.20	7.09	6.03	**8.00**
Mean	**7.45**	**8.27**	**8.17**	**7.84**	**6.57**	**5.52**	**7.31**	**7.39**	**8.29**	**8.06**	**7.53**	**6.12**	**5.36**	**7.12**
SEm± (T / D / T×D)	**0.15 / 0.28 / 0.63**							**0.14 / 0.25 / 0.57**						
CD (P = 0.05) (T / D / T×D)	**0.44 / 0.78 / N.S.**							**N.S. / 0.72 / N.S.**						
T = treatments, D = storage days, N.S. = not significant.														

Lower PLW indicates lower transpiration and respiration, and better cell-wall and membrane integrity in calcium-treated fruit (Chen et al., 2024; Jaime-Guerrero et al., 2024). Bagging can lower water loss by raising humidity around the fruit (Sharma et al., 2014).

3.8 Organoleptic quality

T_{16} received the highest mean organoleptic score in both years (8.12 and 8.00) against 5.48 and 5.17 in the control (Table 9). Scores were highest on day 2 (day mean 8.27 and 8.29) and declined to 5.52 and 5.36 on day 10 (CD for days 0.78 and 0.72); T_{16} scored 6.34 and 6.03 on day 10 against 4.44 and 4.00 in the control. In 2015–16 the treatment effect was significant (CD 0.44). In 2016–17 the treatment effect was not significant (Table 9), so the higher score of T_{16} in that year is reported as numerical only and statistical superiority is claimed for 2015–16 alone.

Higher scores of T_{16} are consistent with its higher sugars and vitamin C, firmer texture and lower weight loss, as reported for bagged guava (Saxena et al., 2021; Kantwa et al., 2023).

3.9 Storage life

The tables record quality over a fixed 10-day period; they do not measure days to loss of marketability. Over this period T_{16} had 73% lower PLW than the control (8.7–8.8% vs 32.7% on day 10), about 2.1–2.2 times the ascorbic acid (84–90 vs 40–42 mg 100 g^{-1}) and a sensory score above 6 (6.03–6.34), while the control scored below 5 (4.00–4.44). This shows better quality retention up to day 10.

3.10 Role of coloured polythene bagging

Bag colour had a clear effect, but it depended on the nutrient treatment (Tables 1, 3, 7 and 8). With $CaCl_2$ alone, blue bags (T_8) gave higher TSS than red, green and yellow bags (13.72 vs 10.67–11.82% in 2015–16; 12.64 vs 9.60–10.85% in 2016–17) and than the unbagged spray T_2 (10.52 and 8.71%). With $CaCl_2$ + K_2SO_4, the blue bag (T_{16}) gave 15.16 and 13.43% TSS against 10.29–11.65 and 9.68–10.73% for the other colours and 10.32 and 10.72% for T_4. Ascorbic acid was highest under blue bags in all three nutrient groups in both years (for example, 154.08 vs 132.98–139.81 mg 100 g^{-1} for K_2SO_4 + other colours in 2015–16). Blue was not best everywhere: with K_2SO_4 alone the red bag gave the highest TSS in 2015–16 (T_9, 14.05% vs 12.84% for T_{12}) and equalled blue in 2016–17 (11.70%) and firmness showed no consistent colour pattern (for example 6.82–6.96 kg cm^{-2} across all four colours with $CaCl_2$ in 2015–16). PLW was lowest under blue bags in all three nutrient groups (T_8 5.11 vs 5.85–5.96%; T_{12} 5.27 vs 5.42–5.84%; T_{16} 4.69 vs 4.98–5.32% in 2015–16), but the advantage over the next best colour exceeded the CD (0.25) only in the $CaCl_2$ and $CaCl_2$ + K_2SO_4 groups.

Bagging modifies the microenvironment surrounding the fruit by altering light, temperature and humidity, while also protecting the fruit against insect pests, pathogens and mechanical injury. These effects may vary depending on bag material and colour (Sharma et al., 2014; Edirimanna et al., 2015; Rahman et al., 2018; Buthelezi et al., 2021). The lower physiological loss in weight (PLW) observed in bagged fruits may be associated with reduced transpiration under higher humidity inside the bags. Changes in light quality may also influence fruit ripening and the accumulation of sugars and ascorbic acid. However, these mechanisms remain hypothetical because the microenvironment inside the bags was not measured. The variation in bagging effects across nutrient treatments suggests a possible interaction between bagging and nutrient sprays. In the absence of bagging-only treatments, the individual contribution of the blue polythene bag to the response observed in T_{16} cannot be distinguished from its combined effect with $CaCl_2$ + K_2SO_4. Therefore, blue polythene bagging may be considered a promising component of the combined treatment, although further experiments incorporating bagging-only controls are needed to confirm its independent effect.

Conclusions

Pre-harvest foliar application of $CaCl_2$ (2%) + K_2SO_4 (2%) combined with blue perforated polythene bagging (T_{16}) resulted in the best overall quality retention of rainy-season guava cv. Lucknow-49 during 10 days of ambient storage across both years of study. This treatment recorded the highest TSS, acidity, ascorbic acid, total and reducing sugars, and organoleptic scores, together with the lowest physiological loss in weight (PLW), approximately one-third that of the untreated control, while maintaining relatively high fruit firmness. Blue bagging was associated with consistently higher ascorbic acid content across nutrient regimes, whereas the reduction in PLW appeared to be influenced substantially by the nutrient treatments. However, in the absence of bagging-only controls, the independent contribution of bagging could not be separated from the combined treatment effect. Therefore, these findings support the potential of integrating blue perforated polythene bagging with $CaCl_2$ + K_2SO_4 sprays for improving postharvest quality retention, although further trials incorporating bagging-only controls are needed to validate the independent effect of bagging.

Declarations

Acknowledgements

The authors thank the Department of Fruit Science and Post Harvest Technology, College of Horticulture and Forestry, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya for orchard, laboratory and technical support.

Author contributions

K.K. Mishra: conceptualisation, investigation, data collection and analysis, writing original draft. **S. Pathak:** supervision, methodology, validation. A. Rao: data interpretation, manuscript editing. **A. Shankar:** statistical analysis, review and editing. All authors read and approved the final manuscript.

Funding

No specific grant from any funding agency in the public, commercial or not-for-profit sectors was received for this work.

Conflict of interest

The authors declare no competing financial interests or personal relationships that could have influenced the work reported here.

Data availability

The data are available from the corresponding author on reasonable request.

Ethical approval

The study involved sensory evaluation of guava fruits by a panel of eight judges. Informed consent was obtained from all panelists before the evaluation. No experimental animals were involved in this study.

References

1. Afroz, S., Mishra, S., & Bahadur, V. (2023). Impact of nutrient application and bagging on development and quality of guava (*Psidium guajava* L.). *International Journal of Plant & Soil Science*, 35(18), 857–864.
2. AMIC-PJTSAU (2024). *Hastha Bahar (Spring Season) 2023-24 Pre-Harvest Price Forecast of Guava*. Agricultural Market Intelligence Centre, Professor Jayashankar Telangana State Agricultural University, Hyderabad.
3. AOAC (2000). *Official Methods of Analysis* (17th ed.). Association of Official Analytical Chemists, Washington, DC.
4. Buthelezi, N. M. D., Mafeo, T. P., & Mathaba, N. (2021). Preharvest bagging as an alternative technique for enhancing fruit quality: A review. *HortTechnology*, 31(1). https://doi.org/10.21273/HORTTECH04658-20
5. Chen, N., Wei, W., Yang, Y., Chen, L., Shan, W., Chen, J., Lu, W., Kuang, J., & Wu, C. (2024). Postharvest physiology and handling of guava fruit. *Foods*, 13(5), 805. https://doi.org/10.3390/foods13050805
6. Cochran, W. G., & Cox, G. M. (1970). *Experimental Designs* (2nd ed.). John Wiley & Sons, New York.
7. Edirimanna, E., Amarathunga, D., Amarasena, B., & Kirinde, T. (2015). Effect of bagging materials and bag colour on fruit weight and quality of guava (*Psidium guajava* L.). *Annals of the Sri Lanka Department of Agriculture*, 17, 297–302.

8. Goswami, A. K., Sharma, R. M., & Kumar, R. (2008). Effect of pre- and post-harvest treatment of calcium on quality and shelf life of guava fruit cv. Sardar. *Acta Horticulturae*, 682, 1281–1286.
9. Hepler, P. K. (2005). Calcium: A central regulator of plant growth and development. *The Plant Cell*, 17(8), 2142–2155. https://doi.org/10.1105/tpc.105.032508
10. Jaime-Guerrero, M., Álvarez-Herrera, J. G., & Fischer, G. (2024). Effect of calcium on fruit quality: A review. *Agronomía Colombiana*, 42(1), e112026. https://doi.org/10.15446/agron.colomb.v42n1.112026
11. Kantwa, R. C., Gurjar, P. K. S., Rana, A., Choudhary, R., Harsha, Prakash, O., & Yadav, S. L. (2023). Effect of pre-harvest treatments and bagging on sensory parameters of guava fruit cv. G-27. *The Pharma Innovation Journal*, 12(9), 3025–3027.
12. Lane, J. H., & Eynon, L. (1923). Determination of reducing sugars by Fehling's solution with methylene blue indicator. *Journal of the Society of Chemical Industry*, 42, 32–37.
13. Larmond, E. (1977). *Laboratory Methods for Sensory Evaluation of Food* (Publication No. 1637). Department of Agriculture, Ottawa, Canada.
14. Magness, J. R., & Taylor, G. F. (1925). An improved type of pressure tester for the determination of fruit maturity. *U.S. Department of Agriculture Circular*, 350, 1–8.
15. Marschner, P. (Ed.) (2012). *Marschner's Mineral Nutrition of Higher Plants* (3rd ed.). Academic Press, London.
16. Rahman, M. M., Hossain, M. M., Rahim, M. A., Rube, M. H. K., & Islam, M. Z. (2018). Effect of pre-harvest fruit bagging on post-harvest quality of guava cv. Swarupkathi. *Fundamental and Applied Agriculture*, 3(1), 363–371.
17. Ranganna, S. (1986). *Handbook of Analysis and Quality Control for Fruit and Vegetable Products* (2nd ed.). Tata McGraw-Hill, New Delhi.
18. Ribeiro, L. R., Leonel, S., Souza, J. M. A., Garcia, E. L., Leonel, M., Monteiro, L. N. H., Silva, M. de S., & Ferreira, R. B. (2020). Improving the nutritional value and extending shelf life of red guava by adding calcium chloride. *LWT*, 130, 109655. https://doi.org/10.1016/j.lwt.2020.109655
19. Ruck, J. A. (1969). *Chemical Methods for Analysis of Fruit and Vegetable Products* (Publication No. 1154). Department of Agriculture, Ottawa, Canada.
20. Saxena, S., Sonkar, P., Patel, N., & Singh, J. (2021). Effect of pre-harvest treatments and bagging on physical characteristics and organoleptic improvement of guava fruits. *The Pharma Innovation Journal*, 10(12), 637–639.
21. Sharma, R. R., Reddy, S. V. R., & Jhalegar, M. J. (2014). Pre-harvest fruit bagging: A useful approach for plant protection and improved post-harvest fruit quality – A review. *Journal of Horticultural Science and Biotechnology*, 89(2), 101–113.
22. Tripathi, V. K., Kumar, N., Pandey, S., Kumar, A., & Tripathi, R. (2026). Effect of foliar application of calcium and potassium on growth, yield and quality of guava (*Psidium guajava* L.). *Journal of Horticultural Sciences*, 21(1). https://doi.org/10.24154/jhs.v21i1.4284
23. White, P. J., & Broadley, M. R. (2003). Calcium in plants. *Annals of Botany*, 92(4), 487–511. https://doi.org/10.1093/aob/mcg164
24. Zaid, A., Singh, B. K., Thakur, N., Singh, S. K., Singh, A., Mishra, V., & Pushpendra (2026). Impact of pre-harvest fruit bagging on biochemical attributes of guava (L-49). *Plant Archives*, 26(Supplement 2), 1373–1377. https://doi.org/10.51470/PLANTARCHIVES.2026.v26.supplement-2.164