



Plant bio-regulators for enhancing quality and storability of Carambola (*Averrhoa carambola*) fruits

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ABSTRACT

Plant bio-regulators are natural and safe phenolic compounds which exhibit a high potential in controlling post-harvest losses of horticultural crops. They act as moisture and gas barriers, preserve colour, texture and moisture, enhance quality and extend the shelf life. The present investigation was conducted at Post-harvest laboratory of Department of Horticulture, Aromatic and Medicinal Plants, Mizoram University, Aizawl during 2016-17 to study the effect of plant bio-regulators in quality of carambola (*Averrhoa carambola* L.), fruits. Total 9 treatments comprising control and different concentrations of Gibberellic Acid, 1-Naphthalene Acetic Acid, 6-Benzylamino Purine, Salicylic Acid were evaluated. The treatments were compared within 16 days at an interval of 4 days. Among the 9 treatments, NAA 100 ppm showed superiority in different quality attributing characters like physiological loss in weight (PLW) (17.33%), fruit firmness (4.62), decay per cent (16.10%), TSS (13.73°Brix), ascorbic acid (8.82 mg/100 g), titratable acidity (0.527%), total sugars (9.97%), reducing sugar (6.37%), TSS: acid ratio (26.15), taste (8.57), appearance (5.79), and overall acceptability (6.70). The same treatment recorded maximum shelf life by maintaining the best quality parameters.

Key words: Bio-regulators, Carambola, Quality, Shelf life

Carambola (*Averrhoa carambola* L.), commonly known as ‘five fingered fruit’ or ‘Golden Star’ is a delicious fruit of family Oxalidaceae. It is most popular in tropical and sub-tropical countries of the world (Narain *et al.* 2001). From the nutrition point of view, the fruit, a blend of sweet and sour, is an important source of natural antioxidants, vitamin C, carotenoids and some phenolic compounds (Shui and Leong 2006). In addition, it is a rich source of insoluble dietary fibres with potential hypoglycemic effects (Chau *et al.* 2004). The unique star shape and rich golden colour, in addition to their use as a fresh fruit and in processing, provides a considerable market potential as a garnish for salads and drinks.

Carambola fruits are perishable in nature and deteriorate very fast after harvest and do not reach consumers at optimal quality after transportation. The main reasons of deterioration are softening, surface pitting, and stem browning. The fruits have very high respiration rates, making their storage and marketing challenging in domestic market. Extending shelf life may be possible by checking the transportation rate, respiration rate and microbial infection. Thus, the development of a simple and inexpensive process for its preservation is important for this fruit. Among the different

methods used to extend the shelf life, application of plant bio-regulators has received attention worldwide. Salicylic acid, an endogenous plant growth regulator, is considered to be a natural and safe phenolic compound exhibiting a high potential in controlling post-harvest losses of horticultural crops, and delays ripening through inhibition of ethylene biosynthesis. Post-harvest application of GA₃ plays an important role in delaying ripening, prolonging shelf life and maintaining postharvest quality of various fruit crops. Application of NAA immediately after picking resulted in prolonged storage life even at unfavourable temperature. However, information on above aspects related to carambola fruit is very scanty, therefore, present experiment was undertaken to study the effect of different post-harvest bio-regulator treatments on its shelf-life and quality.

MATERIALS AND METHODS

Fresh carambola fruits of uniform shape, size, colour, and free from disease and pest were harvested at colour break stage from the experimental farm, Department of Horticulture, Aromatic and Medicinal Plants, Mizoram University, Aizawl. The fruits were washed under running water to remove dust and dirt and treated with chlorinated water (0.25 g/L) as per methods of Garcia *et al.* (1998a, 1998b) and dried using tissue paper. To select the fruits having uniform maturity, the fruits were graded by density gradation method. There were 9 treatments comprising of various plant bio-regulators, i.e. T₁: Gibberellic Acid (GA₃) (25 ppm),

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T₂: Gibberellic Acid (GA₃) (50 ppm), T₃: 1-Naphthalene Acetic Acid (NAA) (50 ppm), T₄: 1-Naphthalene Acetic Acid (NAA) (100 ppm), T₅: 6-Benzylamino Purine (BAP) (5 ppm), T₆: 6-Benzylamino Purine (BAP) (10 ppm), T₇: Salicylic Acid (SA) (100 ppm), T₈: Salicylic Acid (SA) (200 ppm) and T₉: control (Water spray).

For studying the changes in shelf life and physico-chemical characteristics, the boxes containing the fruits were kept under ambient conditions. There were three replications in each treatment and twenty fruits were taken for each replication. The experiment was laid in a completely randomized design. Observations on various physico-chemical attributes of fruits were taken on same day of harvest and on 4, 8, 12, and 16 days of storage. The physiological loss in weight (PLW) of the fruits was calculated on initial weight basis and expressed in percent. Non-destructive fruit firmness was recorded by following the methods of Shahnawaz and Sheikh (2011). The TSS of fruit was measured with Zeiss H and Refractometer of 0–32° Brix range. The acidity, sugar and ascorbic acid of the fruits were determined as per AOAC (2002). Sensory parameters, viz. appearance, taste, flavour and overall acceptability was evaluated by semi-trained panel of judges in the age group of 25–45 (Verma and Joshi 2000). Semi-trained panel included the group of selected panel members who were instructed about the tasting procedure before sensory evaluation and 9- point Hedonic scale (Liked extremely=9, Liked very much=8, Liked moderately=7, Liked slightly=6, Neither liked nor disliked=5, Disliked slightly=4, Disliked moderately=3, Disliked very much=2, Disliked extremely=1). The data obtained from different observations during laboratory analysis were subjected to Fisher's method of analysis of variance (ANOVA). Significance and non-significance of the variance due to different treatments were determined by calculating the respective 'F' value and comparing with the appropriate value of 'F' at 5% probability level (Panse and Sukhatme 1985). By comparing different treatments among themselves critical difference at 5% probability

level and standard error differences was calculated. The significant and non-significant difference of treatments were calculated by multiplying the standard error differences with appropriate tabulated values for error degrees of freedom.

RESULTS AND DISCUSSION

Physiological loss in weight: Different plant bio-regulators have significant effect in reducing the physiological loss in weight of the carambola fruits at various days after storage (Table 1). Among the various treatments, the significantly lowest PLW of 5.22, 8.40, 13.87 and 17.33% after 4, 8, 12 and 16 days of storage, respectively, was recorded with NAA 100 ppm followed by GA 50 ppm and SA 200 ppm. Similarly, the highest PLW of 10.52, 18.87, 25.47 and 32.80% was recorded in control. The plant bio-regulators served as physical barriers around the fruit which partially close the stomatal openings and lenticels, thereby, reducing the rates of transpiration and respiration, delayed ripening by opposing action of ethylene produced during ripening. The highest rate of PLW in control might be due to higher moisture loss and increased respiration through uninterrupted atmospheric column and lower relative humidity as compared to coated fruits (Pongener *et al.* 2011). The present observation is in conformity with the results reported by Patel *et al.* (2011).

Fruit firmness: The fruit firmness, in general followed a declining trend commensurate with advancement in storage period (Table 1). The decrease in firmness with advancement of storage period might be attributed due to change in the turgor of the cell and changes in the composition of cell wall pectins and lipo-protein membrane bordering the cells (Chen *et al.*, 1983). Fruits coated with NAA100 ppm maintained the highest firmness (5.70, 5.25, 5.07 and 4.62) at 4, 8, 12 and 16 days followed by GA₃ 50 ppm (5.57, 5.22, 4.93, and 4.25). The controlled fruits registered the lowest firmness (4.42, 3.72, 3.08 and 2.70). The fruits treated with NAA and GA₃ had better retention of firmness may be due to checking the breakdown of insoluble proto pectin

Table 1 PLW (%), firmness, and decay (%) on different days after storage

Treatment	Physiological loss in weight PLW (%)				Firmness				Decay (%)			
	4 days	8 days	12 days	16 days	4 days	8 days	12 days	16 days	4 days	8 days	12 days	16 days
T ₁	6.55	10.77	15.90	24.50	5.33	4.57	4.12	3.28	4.25	8.63	20.10	22.03
T ₂	5.62	8.97	14.50	18.57	5.57	5.22	4.93	4.25	2.21	3.70	13.80	17.03
T ₃	6.33	11.30	16.33	19.77	5.27	4.71	4.37	3.40	5.30	5.93	16.61	21.47
T ₄	5.22	8.40	13.87	17.33	5.70	5.25	5.07	4.62	1.97	3.20	12.77	16.10
T ₅	7.10	14.07	19.07	24.57	5.33	4.67	3.91	3.58	5.42	7.91	18.43	25.35
T ₆	6.51	11.73	18.47	23.17	5.25	4.53	4.38	3.59	6.36	8.09	15.73	24.23
T ₇	6.87	12.77	17.17	20.17	5.22	4.33	4.37	3.80	5.37	8.79	18.57	22.27
T ₈	5.83	9.77	14.77	19.67	5.50	4.80	4.43	3.98	3.77	5.75	14.46	18.81
T ₉	10.52	18.87	25.47	32.80	4.43	3.72	3.08	2.70	10.75	23.74	37.80	54.33
S Em (±)	0.39	0.66	0.94	0.76	0.16	0.14	0.22	0.16	0.60	1.60	1.17	0.91
CD(P=0.05)	0.82	1.37	1.96	1.58	0.33	0.29	0.47	0.33	1.24	3.33	2.44	1.90

into soluble pectin or by hydrolysis of starch or by cellular disintegration leading to membrane permeability thereby maintaining the firmness better (Mahajan *et al.* 2013). Our study is in close conformity with the findings of Patel *et al.* (2011) in custard apple and Attri *et al.* (2015) in plum.

Decay per cent: It has been observed from the data presented in Table 1 that the decay percent increased significantly with the increase in storage period from 4th to 16th day. On 16th day of storage, the significantly lowest decay (16.10%) was recorded in NAA 100 ppm treated fruits followed by GA₃ 50 ppm (17.03%) and SA 200 ppm (18.81%) as compared to maximum in control (54.33%). The less spoilage in these treatments might be due to filling of the lenticels and left no places for entry of pathogens like fungi and bacteria, which reduce parenchymatous tissue to watery mass and hence less spoilage. Similar findings in different fruit crops have also been observed by Patel *et al.* (1994) in guava.

Total soluble solids (TSS): It is evident from the data presented in Table 2 that TSS of the fruits increased with the storage period from 4th day to 16th days of storage irrespective of the treatments. The increase in TSS with the storage period may possibly be due to breakdown of complex organic metabolites into simple molecules or due to hydrolysis of starch into sugars. There was significant difference among the fruits treated with different plant bio-regulators with respect to TSS of the fruits. On 16th day, fruits in control had lowest TSS (10.43°Brix) and NAA 100 ppm had recorded the highest TSS (13.73°Brix). The increase in TSS in NAA treated fruits, indicate the possible role of NAA in delaying metabolic activities of fruits during ripening and storage. It might also be due to restriction in the physiological process and respiration during storage thereby maintaining the total soluble solids better as compared to the fruits under control (Attri *et al.* 2015). Our results are in conformity with those reported by Mahajan *et al.* (2004) in Asian pear.

Ascorbic acid: The perusal of the data presented in Table 2 revealed that the ascorbic acid is decreased with the

advancement of storage period, irrespective of treatments. Among all the treatments, the maximum ascorbic acid at the end of storage period was found in the fruits treated with NAA 100 ppm (8.82 mg/100 g). This could possibly be due to retardation of oxidation process and consequently slow rate of conversion of L-ascorbic acid into dehydroascorbic acid by ascorbic acid oxidase. The retention of higher ascorbic acid in NAA treated fruits might be due to the ripening retarding effect and slow rate of biological activities during storage. Similar observations have also been recorded in mango (Jain and Mukherjee 2011) and mandarin orange (Yadav *et al.* 2010).

Titrateable acidity: Data pertaining to titrateable acidity as influenced by different treatments are presented in Table 2. The titrateable acidity of the fruits decreased with the storage period irrespective of the treatments. The decrease in TA with the increase in storage period could possibly be attributed to the decreased hydrolysis of organic acids in pyruvate decarboxylation reaction occurring during the ripening process and subsequent accumulation of organic acids which were oxidised at a slow rate because of decreased respiration. Among all the treatments, at the end of storage period, minimum titrateable acidity was found in the fruits treated with NAA 100 ppm (0.523%), followed by GA₃ 50 ppm (0.593%) and SA 200 ppm (0.657%). The significantly lower acidity in these treatments might be due to utilization of acid in the respiratory process or conversion of acid into sugars and its derivatives by the reaction of glycolytic pathway by these bio-regulators.

Total sugars: The total sugars of the fruits increased with storage period from 4th days to 16th days of storage irrespective of treatments as shown in the Table 3. At 16 days of storage, highest total sugars was recorded in NAA 100 ppm (9.97%) while, the lowest (8.88%) was recorded in control. The increase in total sugars of fruits with NAA might be due to loss of water from the fruits and conversion of polysaccharides and pectic substances into sugars. The higher rate of acceleration in NAA treated fruits may be due to retardation in the rate of normal changes of

Table 2 TSS, Ascorbic Acid, and Titrateable acidity on different days after storage

Treatment	TSS (°Brix)				Ascorbic Acid (mg/100 g)				Titrateable acidity (%)			
	4 days	8 days	12 days	16 days	4 days	8 days	12 days	16 days	4 days	8 days	12 days	16 days
T ₁	7.92	9.66	11.84	12.80	24.70	19.66	10.40	8.49	1.460	0.860	0.830	0.727
T ₂	8.83	10.57	12.62	13.67	25.93	20.55	12.23	8.74	1.277	0.780	0.760	0.593
T ₃	8.38	10.16	11.78	12.75	25.08	16.35	9.73	8.51	1.370	0.817	0.773	0.753
T ₄	8.90	10.64	12.69	13.73	26.19	20.81	12.39	8.82	1.077	0.713	0.673	0.527
T ₅	7.83	9.57	11.62	12.67	23.16	15.97	9.92	8.43	1.330	0.923	0.780	0.787
T ₆	8.47	9.94	11.71	13.03	22.47	15.97	9.50	8.32	1.430	0.903	0.830	0.713
T ₇	8.23	9.81	12.19	12.90	22.52	16.02	9.53	8.36	1.500	0.837	0.807	0.693
T ₈	8.63	10.37	12.32	13.47	25.51	19.71	11.70	8.56	1.273	0.760	0.733	0.687
T ₉	6.93	8.67	9.72	10.43	19.07	14.57	8.67	7.85	1.687	1.117	0.907	0.930
S Em (±)	0.23	0.27	0.25	0.37	0.93	0.65	0.96	0.15	0.097	0.054	0.046	0.079
CD (P=0.05)	0.48	0.56	0.51	0.77	1.94	1.36	2.00	0.31	0.202	0.113	0.095	0.165

Table 3 Total sugars, reducing sugars and TSS: acid ratio on different days after storage

Treatment	Total sugars (%)				Reducing sugars (%)				TSS: Acid ratio			
	4 days	8 days	12 days	16 days	4 days	8 days	12 days	16 days	4 days	8 days	12 days	16 days
T ₁	8.37	8.62	9.00	9.42	4.88	5.18	5.76	6.10	5.44	11.24	13.62	17.66
T ₂	8.53	8.83	9.32	9.74	4.94	5.32	5.67	6.24	6.92	13.59	16.61	23.36
T ₃	8.43	8.63	9.25	9.59	4.85	5.23	5.98	6.06	6.14	12.47	15.28	16.97
T ₄	8.73	9.02	9.54	9.97	5.16	5.53	5.55	6.37	8.54	15.07	19.02	26.15
T ₅	8.17	8.51	9.27	9.65	4.73	5.10	5.42	6.04	5.91	10.41	14.91	16.26
T ₆	8.20	8.61	9.27	9.66	4.59	4.97	5.47	6.08	5.93	11.08	14.23	18.29
T ₇	8.30	8.46	9.01	9.44	4.65	5.03	5.54	6.12	5.51	11.72	15.10	18.62
T ₈	8.48	8.77	9.33	9.45	4.93	5.26	5.36	6.15	6.82	13.76	16.81	19.67
T ₉	8.07	8.31	8.68	8.88	4.54	4.91	5.76	5.86	4.12	7.79	10.77	11.61
S Em (±)	0.14	0.16	0.09	0.12	0.12	0.09	0.08	0.07	0.62	0.90	0.93	1.44
CD (P=0.05)	0.29	0.33	0.19	0.25	0.25	0.19	0.17	0.14	1.28	1.88	1.93	3.00

polysaccharides to total sugars because of its low rate of respiration and oxidation in treated fruits.

Reducing sugars: Various plant bio-regulators had significant effect on amount of reducing sugar from 4th days of storage till 16th days of storage. Fruits treated with NAA had the maximum reducing sugars (6.37%) while the control had the lowest reducing sugars (5.86%) at end of storage period. The progressive increase in reducing sugars during storage period might be due to metabolic transformation of soluble compounds and more conversion of organic acid into sugars.

TSS: Acid ratio: It has been observed from the data presented in Table 3 that the TSS: Acid ratio increased with the storage period till 16th days of storage irrespective of all the treatments. At 16th day of storage, the fruits treated with NAA 100 ppm had significantly highest TSS: Acid ratio (26.15), while the lowest was recorded in control (11.61). The highest TSS: Acid ratio in NAA treated fruits might be due to more moisture loss from the fruits leading to more concentration of juice resulting in higher sugar content whereas maximum decrease in acidity of fruits

treated with NAA may be ascribed to increased respiration rate and more utilization of acids in biochemical activities leading to depletion of organic acids.

Taste: The carambola fruits showed a steady increase in the taste of the fruits up to 16th day of storage (Table 4). The significantly maximum score with respect to taste at 16 days of storage was recorded in NAA 100 ppm (8.57). The gradual increase in the taste has been attributed to the increase in the concentration of total sugars and TSS. The highest value of taste in NAA treated fruits might be attributed due to highest TSS and total sugars on 16th days of storage.

Appearance: The fruits treated with NAA 100 ppm had shiny appearance and showed no wrinkles or browning, therefore scoring maximum value with respect to appearance (5.79) followed by GA₃ 50 ppm (5.66), and SA 200 ppm (5.49) on 16 days of storage, while, control registered the minimum value with respect to appearance (4.39). The development of better appearance in the NAA treated fruits could possibly be due to creation of favourable gaseous atmosphere under congenial temperature.

Table 4 Taste, appearance, overall acceptability and shelf life under different treatments on different days after storage

Treatment	Taste				Appearance				Overall acceptability				Shelf life (days)
	4 days	8 days	12 days	16 days	4 days	8 days	12 days	16 days	4 days	8 days	12 days	16 days	
T ₁	7.23	7.43	6.80	7.03	6.97	6.80	5.90	5.02	7.53	7.23	6.17	5.83	11.47
T ₂	7.37	7.70	8.07	8.30	7.73	7.47	6.40	5.66	8.27	8.00	7.43	6.67	14.43
T ₃	7.20	7.43	7.80	7.97	6.80	6.57	6.23	5.19	7.37	7.10	6.83	5.93	12.83
T ₄	7.70	8.13	8.33	8.57	7.83	7.67	6.53	5.79	8.30	8.07	7.63	6.70	14.90
T ₅	6.33	6.60	6.97	7.17	6.77	6.50	5.53	4.79	6.87	6.57	6.13	5.87	11.27
T ₆	6.50	6.77	7.13	7.37	6.53	6.33	5.50	4.76	7.07	6.83	6.13	6.10	10.33
T ₇	6.00	6.53	6.93	7.23	6.87	6.73	6.20	4.46	6.77	6.40	5.97	5.87	11.43
T ₈	7.30	7.50	7.97	8.03	7.53	7.13	5.97	5.49	8.10	7.80	6.73	6.47	14.30
T ₉	5.57	6.23	6.50	6.67	6.23	5.80	5.13	4.39	6.23	5.93	5.50	4.57	6.63
S Em (±)	0.20	0.28	0.22	0.27	0.24	0.33	0.28	0.20	0.21	0.16	0.19	0.12	0.30
CD (P=0.05)	0.41	0.59	0.47	0.57	0.50	0.69	0.58	0.42	0.44	0.33	0.39	0.26	0.62

Overall acceptability: The carambola fruits showed a gradual and steady decline in the overall acceptability of the fruits with the increase in storage period (Table 4). The fruits treated with NAA 100 ppm had the highest score (6.70) on 16th days of storage followed by GA₃ 50 ppm (6.67), and SA 200 ppm (6.47). The overall acceptability of carambola fruits depends on a delicate balance of sugars, acids, phenolic and aromatic compounds with a number of additional factors such as pulp texture and visual appearance that influence the perceived quality and consumer acceptance and appreciation. The highest score in NAA treated fruits might be due to superiority in all the above mentioned factors. The lowest score in control might be due to skin injury which further caused tissue softening and deflection of colour pigments leading to change in overall acceptability of fruits (Hazarika *et al.*, 2019)

Shelf life: Among all the treatments, fruits coated with NAA 100 ppm have maximum shelf life of 14.90 days followed by GA₃ 50 ppm, and SA 200 ppm, while control recorded the lowest shelf life of 6.63 days. The positive effect of NAA on storage life could probably be due to the modified atmosphere. The modified atmosphere created could, therefore, delay the ripening by delaying ethylene production and by reducing the level of internal oxygen and consequently prolonging the storage life of fruit (Gol and Rao 2011).

The present investigation revealed that plant bio-regulators have significant effect in extending the shelf life of carambola fruits. From the results of the present investigation, it can be concluded that among all the plant bio-regulators, NAA 100 ppm was the best among for improvement of quality parameters as well as extending the shelf life of carambola fruits.

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