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The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(11): 1623-1626

www.thepharmajournal.com
Received: 18-09-2022
Accepted: 25-10-2022

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Effect of post-harvest treatments on physiological parameters of aonla cv. Chakaiya

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Abstract
The experiment was carried out at Post-harvest Laboratory, Department of Horticulture, College of Agriculture, CCSHAU, Hisar to find out effect of post-harvest chemicals on physiological parameters of aonla under ambient storage conditions. The fruits were treated with different concentration of GA_3 (400, 500 and 600 ppm), $Ca(NO_3)_2$ (1.0, 2.0 and 3.0%), $KMnO_4$ (1000, 2000 and 3000 mg) and bael leaf extract (2.0, 3.0 and 4.0%) and packed in perforated polythene bags and stored at ambient temperature. The physiological changes were faster in untreated fruits (control). Post-harvest treatment with 1.0% $Ca(NO_3)_2$, followed by 600 ppm GA_3 were recorded lower physiological loss in weight, moisture and decay loss throughout the storage period. The maximum fruit firmness and specific gravity were observed in calcium nitrate 1.0% treated fruits. Among treatments, fruits treated with GA_3 600 ppm had showed better colour retention.

Keywords: Decay loss, fruit firmness, aonla, post-harvest treatments, polythene bags, physiological parameters

Introduction
The Indian gooseberry (*Emblica officinalis* Gaertn. Syn. *Phyllanthus emblica*) is a member of the Euphorbiacea family and is known as Aonla in India. It is rich source of vitamin C and its ascorbic acid level is second only to the Barbados cherry (Chadha, 2002) [4]. Due to its highly acidic and astringent nature, consumers do not prefer this fruit in its natural state, thus it is usually eaten in processed forms such as jam, jelly, murabba, candy, pickles, herbal jam, sauce, and so forth (Singh, 2014) [16]. It is commercially utilised to make ayurveda tonics such as Chavyanprash and triphala (Goyal *et al*., 2007 and Singh *et al*., 2012) [24 18]. Aonla fruits are highly perishable and difficult to store or transport across long distances. As a result, it requires quick marketing and utilization. It becomes necessary to keep the fruits for a long time in order to get a decent return and avoid market glut. The shelf life of aonla fruits could be extended by reducing the respiration rate, water loss through transpiration (Dhumel *et al*., 2008) [5] and limiting various post-harvest diseases mainly blue mould (*Penicillium citrinum*) and other diseases caused by Rhizopus, Aspergillus and *Syncephalastrum racemosum* (Singh *et al*., 2005) [17]. Plant growth regulators and certain chemicals play a vital role for short period storage. (Dhumel *et al*., 2008) [5]. To combat post-harvest losses in perishable commodities such as aonla, the current study looked into the effects of various plant growth regulators, chemical solutions, and plant leaf extracts on the physiological parameters of aonla fruits during storage.

Materials and Method
Site of study: Fresh fruits of aonla cv. Chakaiya of uniform shape, size, colour and free from bruises were harvested from Horticulture farm, CCS Haryana Agricultural University, Hisar at the physiological mature stage during the morning hours and brought to the laboratory immediately and further investigation was carried out in Post-harvest Laboratory, Department of Horticulture, College of Agriculture, CCSHAU, Hisar during 2020 to 2021. The experimental region is situated at 215.2 m above sea level with coordinates of 29º10′ N latitude and 75º46′ E longitudes.

Treatments and methods of analysis: The selected fruits were treated with aqueous solution of different concentration of GA_3(400, 500 and 600 ppm), $Ca(NO_3)_2$ (1.0, 2.0 and 3.0%) and bael leaf extract (2.0, 3.0 and 4.0%) each for 10 minutes and then fruits were air dried.

In case of potassium permanganate treatment, the potassium permanganate (1000, 2000 and 3000 mg) was kept in small piece of cloth and placed along with fruits. The untreated fruits were kept as a control. Then fruits were packed in perforated PE bags and stored at room temperature. All the parameters were analysed at an intervals of 2 days up to 12 days. The physiological loss in weight was calculated by the following formula.

$$PLW\ (\%) = \frac{\text{Initial weight (g)} - \text{final weight (g)}}{\text{Initial weight (g)}} \times 100$$

Decay loss (%) of fruits was evaluated on the basis of visual observations by counting the number of spoiled fruits displaying fungal infection and subsequent rotting in a replication and expressed in percentage. Fruit firmness was measured by using cylindrical plunger probe of 4 mm of penetrometer. The change in colour during the storage period was determined on visual basis. The moisture percentage in the fruits was estimated by drying known weight of sample at 70 ºC for 24 hours to a constant weight (A.O.A.C., 1990) [1]. Water displacement method was carried out to measure specific gravity of fruits.

Statistical analysis: The experiment was carried out in Completely Randomized Design (factorial) for analysis of variance (ANOVA) and each treatment was replicated thrice. The data were analysed with the help of OPSTAT statistical software.

Results and Discussion

Physiological loss in weight (%)

It is evident from the Table 1 that different treatments influenced the physiological loss in weight significantly. The minimum (6.82%) physiological loss in weight was recorded in calcium nitrate 1.0% treated fruits, which was statistically at par with calcium nitrate 2.0% (6.99%), whereas the maximum (8.86%) PLW was observed in control. Physiological loss in weight of aonla fruits significantly increased with increasing period of storage irrespective of treatments. The increased physiological weight loss in fruits must be due to various physiological mechanisms such as upsurged respiration and transpiration rate (Singh *et al*., 2003 and Neeraj *et al*., 2002) [19, 13]. However, minimum weight loss was observed in calcium nitrate 1.0% treated fruits which might be due to characteristics of calcium to control the respiration rate by limiting the disintegration of cytoplasmic membranes, mitochondria and endoplasmic reticulum, which results into enhancement of shelf life of aonla (Dhumal *et al*., 2008) [25]. The findings of present experiment corroborate the findings of Singh *et al*. (2014) [16] and Gangwar *et al*. (2012) [7] in aonla, Ranjan *et al*. (2005) [15] in Langra mango and Bhooriya *et al*. (2018) [3] in guava.

Decay loss (%)

The data on decay loss in fruits as influenced by different treatments during storage have been presented in the Table 2 revealed that the decay loss was recorded highest (8.88%) in control fruits, whereas lowest (3.66%) decay loss was recorded in calcium nitrate 1.0%, which was statistically at par with gibberellic acid 600 ppm (3.79%). This is because calcium nitrate provides resistance against pathogens like fungi which are causative factors for rotting of fruits and calcium assists in maintaining the cell wall integrity and maintain the shelf life of fruits for longer period (Lodhi and Tiwari, 2017) [12]. Similar results were obtained by Yadav and Shukla (2009) [22] and Gangwar *et al*. (2012) [7] in aonla, Ranjan *et al*. (2005) [15] in mango and Gangle *et al*. (2019) [6] in guava.

Fruit firmness (Kg-`f)

It is evident from the Table 2 that different treatments influenced the fruit firmness significantly and firmness showed decreasing trend with passage of time. The highest (16.02Kg-`f) fruit firmness was recorded in calcium nitrate 1.0% treated fruits, which was statistically at par with calcium nitrate 2.0% (15.99Kg-`f), potassium permanganate 3000 mg (15.91Kg-`f), calcium nitrate 3.0% (15.82Kg-`f) and gibberellic acid 600 ppm (15.75Kg-`f), whereas the minimum (14.71 Kg-`f) fruit firmness was recorded in untreated fruits. Zeraatgar *et al*. (2018) [23] proposed that calcium maintains cell membrane integrity, tissue firmness and cell turgor, as a result, it maintains the firmness of fruits. Thus, calcium nitrate gave the best results as compared to other treatments to retain better quality of aonla fruit up to 12th days of storage. Similar results were obtained by (Rabiei et al., 2011) [14] in apple.

Table 1: Effect of post-harvest treatments on physiological loss in weight (%) and decay loss (%) of aonla fruits during storage

Treatments	PLW (%)							Decay loss (%)						
	Storage period (days)													
	2	4	6	8	10	12	Mean	2	4	6	8	10	12	Mean
GA_3 400 ppm	1.43	4.45	7.79	9.69	11.12	13.19	7.95	0	2.44	2.44	4.88	9.76	14.64	5.69
GA_3 500 ppm	1.39	4.31	7.55	9.4	10.79	12.79	7.7	0	0	2.33	4.65	9.3	11.63	4.65
GA_3 600 ppm	1.32	4.11	7.2	8.96	10.28	12.19	7.34	0	0	2.27	2.27	6.82	11.37	3.79
$Ca(NO_3)_2$ 1%	1.23	3.82	6.68	8.32	9.55	11.32	6.82	0	0	2.44	2.44	7.32	9.76	3.66
$Ca(NO_3)_2$ 2%	1.26	3.91	6.85	8.53	9.79	11.6	6.99	0	0	4.45	4.45	6.67	13.34	4.82
$Ca(NO_3)_2$ 3%	1.34	4.18	7.32	9.11	10.46	12.4	7.47	0	0	2.38	4.76	9.53	14.29	5.16
$KMnO_4$ 1000 mg	1.41	4.39	7.68	9.56	10.98	13.01	7.84	0	2.33	4.65	4.65	9.3	16.29	6.2
$KMnO_4$ 2000 mg	1.36	4.24	7.42	9.24	10.6	12.57	7.57	0	2.27	2.27	6.82	11.37	15.92	6.44
$KMnO_4$ 3000 mg	1.29	4.01	7.02	8.74	10.03	11.89	7.16	0	0	4.35	4.35	10.87	13.05	5.44
Bael leaf extract 2%	1.51	4.7	8.22	10.23	11.74	13.92	8.39	0	2.33	6.98	9.3	11.63	18.61	8.14
Bael leaf extract 3%	1.49	4.62	8.09	10.07	11.56	13.7	8.25	0	2.27	4.55	6.82	13.64	18.19	7.58
Bael leaf extract 4%	1.47	4.58	8.01	9.97	11.44	13.56	8.17	0	2.22	4.45	6.67	11.11	17.78	7.04
Control	1.59	4.96	8.68	10.8	12.4	14.7	8.86	2.27	4.55	6.82	11.37	15.92	22.74	10.61
Mean	1.39	4.33	7.58	9.43	10.83	12.84		0.18	1.42	3.88	5.65	10.25	15.2	
CD at 5% level of significance	Treatment (T) = 0.17 Storage period (S) = 0.11 T×S = 0.41							Treatment (T) = 0.13 Storage period (S) = 0.08 T×S = 0.31						

Change in colour

The data pertaining to colours presented in Table 2 showed that fruit colour altered with enhancing storage period in fruits treated with various treatments. Change in colour might be due to the breakdown of chlorophyll and synthesis of caroteniod pigments especially yellow pigment during the storage because of enzymatic reactions (Kumari, 2016) [11]. The colour of fruits in all treatments was yellowish green on initial day, but on 4th day of storage, it altered to greenish yellow except in fruits treated with gibberellic acid 600 ppm or calcium nitrate 2.0%. In the end of storage period, all fruits turned yellow in colour except the fruits remained light yellow, which were treated with gibberellic acid 600 ppm, whereas bael leaf extract 2% treated fruits and untreated fruits turned into brownish yellow. Talat *et al*. (2020) [20] suggested that gibberellic acid helps in delaying chlorophyll degradation and inhibits the biosynthesis and accumulation of beta-crypoxanthin. The findings of present experiment corroborate the findings of Kumar *et al*. (2012) [10] in guava fruits and Abdallah and Abu-Goukh (2010) [2] in lime fruits.

Moisture (%)

The data pertaining to moisture is presented in Table 5 showed that in all the treatments, moisture of fruits decreased with passage of time and there was significant difference in moisture percent in fruits of all the treatments as compared to control and the maximum (83.16%) moisture was observed in calcium nitrate 1.0% treated fruits, which was statistically at par with calcium nitrate 2.0% (83.07%), potassium permanganate 3000 mg (82.07%) and gibberellic acid 600 ppm (81.89%), whereas the minimum (75.05%) moisture was recorded in untreated fruits. This might be due to attribute of calcium to control the disintegration of cytoplasmic membranes, mitochondria and endoplasmic reticulum and declines the rate of respiration and conserves the moisture loss from fruits (Dhumal *et al*., 2008) [25]. The results of present experiment are in close agreement with the findings of Jayachandran *et al*. (2004) [9] in guava.

Table 2: Effect of post-harvest treatments on fruit firmness (Kg-`f) and change in colour of aonla fruits during storage

Treatments	Fruit firmness (Kg-`f)							Colour					
	Storage period (days)												
	2	4	6	8	10	12	Mean	2	4	6	8	10	12
GA_3 400 ppm	16.53	16.47	15.57	14.93	14.2	14.07	15.29	YG	GY	GY	LY	Y	Y
GA_3 500 ppm	16.4	16.23	15.8	15.47	14.23	14	15.36	YG	GY	GY	LY	LY	Y
GA_3 600 ppm	16.58	16.53	16.1	15.77	14.83	14.67	15.75	YG	YG	GY	GY	LY	LY
$Ca(NO_3)_2$ 1%	16.5	16.4	16.27	16.1	15.67	15.2	16.02	YG	GY	GY	LY	LY	Y
$Ca(NO_3)_2$ 2%	16.47	16.37	16.23	16.07	15.63	15.17	15.99	YG	YG	GY	GY	LY	Y
$Ca(NO_3)_2$ 3%	16.57	16.53	16.17	15.9	15.03	14.73	15.82	YG	GY	GY	GY	LY	Y
$KMnO_4$ 1000 mg	16.57	16.43	15.93	15.57	14.27	14.02	15.47	YG	GY	LY	LY	Y	Y
$KMnO_4$ 2000 mg	16.53	16.5	16	15.63	14.87	14.47	15.67	YG	GY	LY	LY	Y	Y
$KMnO_4$ 3000 mg	16.5	16.4	16.17	16	15.4	14.97	15.91	YG	GY	GY	LY	LY	Y
Bael leaf extract 2%	16.33	16.13	15.47	14.93	13.93	13.77	15.09	YG	GY	LY	LY	Y	BY
Bael leaf extract 3%	16.3	16.13	15.53	15.07	14.1	13.87	15.17	YG	GY	GY	LY	Y	Y
Bael leaf extract 4%	16.37	16.17	15.63	15.23	14.03	13.87	15.22	YG	GY	GY	LY	Y	Y
Control	16.14	15.77	15.05	14.5	13.57	13.23	14.71	GY	GY	LY	Y	Y	BY
Mean	16.45	16.31	15.84	15.47	14.6	14.31							
CD at 5% level of significance	Treatment (T) = 0.27 Storage period (S) = 0.18 T×S = NS												

Initial fruit firmness= 16.63

Initial colour= YG

YG: Yellowish green, GY: Greenish yellow, LY: Light yellow, Y: Yellow, BY: Brownish yellow

Specific gravity: The data on specific gravity in fruits as influenced by different treatments have been presented in the Table 6 revealed that specific gravity decreased continuously with the enhancement of storage period and among treatments, calcium nitrate 1.0% had the highest (1.014) specific gravity, which was statistically at par with calcium nitrate 2.0% (1.012), gibberellic acid 600 ppm (1.008), calcium nitrate 3.0% (1.006) and potassium permanganate 3000 mg (1.003), whereas the least (0.987) was recorded in control. This might be associated with less reduction in weight of calcium nitrate 1.0% treated fruits during storage and thus, helps in maintaining fruit quality.

Table 3: Effect of post-harvest treatments on fruit firmness (Kg-`f) moisture (%) and specific gravity of aonla fruits during storage

Treatments	Moisture (%)							Specific gravity						
	Storage period (days)													
	2	4	6	8	10	12	Mean	2	4	6	8	10	12	Mean
GA_3 400 ppm	83.97	82.35	81.08	79.25	77.65	76.38	80.11	1.083	1.046	0.999	0.977	0.959	0.928	0.999
GA_3 500 ppm	84.17	82.71	81.57	79.87	78.39	77.21	80.65	1.085	1.047	1.002	0.98	0.963	0.933	1.002
GA_3 600 ppm	84.73	83.73	82.94	81.3	79.87	78.74	81.89	1.089	1.057	1.006	0.985	0.969	0.94	1.008
$Ca(NO_3)_2$ 1%	84.93	84.1	83.44	82.74	82.13	81.64	83.16	1.091	1.063	1.012	0.992	0.977	0.949	1.014
$Ca(NO_3)_2$ 2%	85.27	84.7	84.26	82.68	81.3	80.21	83.07	1.091	1.062	1.01	0.99	0.974	0.946	1.012
$Ca(NO_3)_2$ 3%	84.28	82.92	81.84	80.6	79.53	78.89	81.34	1.088	1.052	1.005	0.984	0.967	0.937	1.006
$KMnO_4$ 1000 mg	84.07	82.54	81.34	79.41	77.73	76.39	80.25	1.084	1.046	1.004	0.979	0.961	0.93	1.001
$KMnO_4$ 2000 mg	84.43	83.19	82.21	81.07	80.08	78.67	81.61	1.086	1.048	1.004	0.982	0.965	0.935	1.003
$KMnO_4$ 3000 mg	84.78	83.82	83.07	81.44	80.02	79.29	82.07	1.09	1.06	1.008	0.988	0.971	0.943	1.01
Bael leaf extract 2%	83.24	81.05	79.32	76.55	74.13	72.21	77.75	1.081	1.037	0.994	0.971	0.953	0.92	0.993
Bael leaf extract 3%	83.44	81.41	79.81	76.98	74.51	72.55	78.12	1.081	1.037	0.996	0.973	0.955	0.923	0.994

Bael leaf extract 4%	83.7	81.87	80.43	78.09	76.05	74.43	79.1	1.082	1.038	0.997	0.974	0.956	0.924	0.995
Control	82.66	79.99	77.89	73.49	69.66	66.61	75.05	1.077	1.032	0.989	0.965	0.945	0.912	0.987
Mean	84.13	82.65	81.48	79.5	77.77	76.4		1.085	1.048	1.002	0.98	0.963	0.932	
CD at 5% level of significance	Treatment (T) = 1.32 Storage period (S) = 0.90 T×S = NS							Treatment (T) = 0.011 Storage period (S) = NS T×S = NS						

Initial moisture=85.97
Initial specific gravity=1.112

Conclusion

From the present investigation, it can be concluded that $Ca(NO_3)_2$ 1.0% and GA_3 600 ppm were found promising in improving the various physiological parameters of fruits. It was revealed by the results that the fruits treated with calcium nitrate 1.0% significantly reduced the physiological loss in weight and decay loss and maximum fruit firmness, specific gravity and moisture were observed in calcium nitrate 1.0% treated fruits. Fruits treated with GA_3 600 ppm had showed better colour retention.

References

1. AOAC. Official Methods of Analysis. 15th Edition, Association of Official Analytical Chemist, Washington, D. C; c1990.
2. Abdallah EH, Abu-Goukh AA. Effect of gibberellic acid and waxing on quality and storability of lime fruits. University of Khartoum Journal of Agricultural Sciences. 2010;18(3):349-362.
3. Bhooriya MS, Bisen BP, Pandey SK. Effect of post-harvest treatments on shelf life and quality of Guava (*Psidium guavajava*) fruits. International Journal of Chemical Studies. 2018;6(4):2559-2564.
4. Chadha KL. Hand book of horticulture. ICAR, New Delhi, India; 2002. p. 5-6.
5. Dhumel SS, Karole AR, Garande VK, Patil BT, Masalkar SD, Kshirsagar DB. Shelf life of aonla fruits: Influenced by post harvest treatments and packaging materials. Indian Journal of agricultural research. 2008;42:189-194.
6. Gangle A, Kirar SK, Pandey CS. Effect of post-harvest treatments on shelf life and quality of guava (*Psidium guajava* L.) cv. Allahabad Safeda. International Journal of Current Microbiology and Applied Sciences. 2019;8(10):2104-2114.
7. Gangwar S, Shukla HS, Katiyar D, Pandey V. Effect of calcium nitrate on physico-Chemical changes and shelf-life of aonla (*Emblica officinalis* Gaertn.) fruits cv. Banrasi, Krishna, kanchan and NA-7. HortFlora Research Spectrum. 2012;1(3):253-258.
8. Goyal RK, Patil RT, Kingsly ARP, Walia H, Kumar P. ‘Status of post-harvest technology of aonla in India’ – A review. American Journal of Food Technology. 2008;3:13-23.
9. Jayachandran KS, Srihari D, Reddy YN, Rao CLN. Influence of post-harvest calcium treatment on storage quality of Lucknow-49 guava. Crop Research. 2004;28(1/3):60-62.
10. Kumar R, Shant L, Kumar M. Effect of post-harvest packaging material and calcium treatments on the quality of guava during storage. Annals of Horiculture 2012;4(2):165-170.
11. Kumari P. Studies on biochemical and antioxidant changes in aonla (*Emblica officinalis* G.) and its different products during storage (Doctoral dissertation, Chaudhary Charan Singh Haryana Agricultural University, Hisar); c2016.
12. Lodhi DK, Tiwari R. Effect of calcium nitrate on physico-chemical changes and shelf-life of aonla (*Emblica officinalis* Gaertn.) fruits. Annals of Plant and Soil Research. 2017;19(1):32-36.
13. Neeraj, Kumar S, Kumar J, Godara RK. Effect of different polythene bags on phenols, chlorophyll and carotenoid content of aonla fruits during room temperature storage. Haryana Journal of Horticultural Sciences. 2002;31:189-191.
14. Rabiei V, Shirzadeh E, Sharafi Y, Mortazavi N. Effects of post-harvest applications of calcium nitrate and acetate on quality and shelf-life improvement of Jonagold apple fruit. Journal of Medicinal Plants Research 2011;5(19):4912-4917.
15. Ranjan A, Raj RN, Prasad, KK. Effect of post-harvest application of calcium salts and GA_3 on storage life of mango (*Mangifera indica* L.) cv. Langra. Journal of Applied Biology Patna India. 2005;15:69-73.
16. Singh AK, Shukla HS, Kumar H, Singh V, Singh RR. Effect of gibberelic acid and calcium nitrate on the physiological and physico-chemical changes and shelf life of aonla (*Emblica officinalis* Gaertn) fruits. International Journal of Farm Science. 2014;5(2):140-145.
17. Singh BP, Pandey G, Sarolia DK, Pandey MK, Pathak RK. Shelf-life evaluation of aonla cultivars. Indian Journal of Horticulture. 2005;62(2):137-140.
18. Singh J, Koul R, Bhat A, Sood M, Bandral JD. Comparative studies on compositional changes on aonla supari (*Emblica officinalis*) during storage. Annals of Food Science and Technology. 2012;13(1):19-24.
19. Singh S, Singh AK, Joshi HK. Storage behaviour of Indian gooseberry (*Emblica officinalis* Gaertn) cultivars in semi-arid ecosystem of Gujarat. Indian Journal of Agricultural Research. 2003;73:530-534.
20. Talat H, Shafqat W, Qureshi MA, Sharif N, Raza MK, ud Din S *et al*. Effect of gibberellic acid on fruit quality of kinnow mandarin. Journal of Global Journal in Agricultural and Social Sciences. 2020;8(2):59-63.
21. Thokchom R, Mandal G. Qualitative analysis of mango cv. Langra influenced by various post-harvest treatments. International Journal of Chemical Studies. 2018;7(1):2167-2172.
22. Yadav S, Shukla HS. Effect of various concentrations of plant growth regulators and mineral nutrient on quality parameters and shelf-life of aonla (*Emblica officinalis* Gaertn) fruits. Indian Journal of Agricultural Biochemistry. 2009;22(1):51-56.
23. Zeraatgar H, Davarynejad GH, Moradinezhad F, Abedi B. Effect of salicylic acid and calcium nitrate spraying on qualitative properties and storability of fresh jujube fruit (*Ziziphus jujube* Mill.). Notulae Botanicae Horti Agrobotanici Cluj-Napoca. 2018;46(1):138-147.
24. Goyal A, Singh NP. Consumer perception about fast food in India: an exploratory study. British food journal; c2007 Feb 20.
25. Dhumal RS, Biradar SV, Yamamura S, Paradkar AR, York P. Preparation of amorphous cefuroxime axetil nanoparticles by sonoprecipitation for enhancement of bioavailability. European Journal of Pharmaceutics and Biopharmaceutics. 2008 Sep 1;70(1):109-15.