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Effect of pre harvest sprays of chemicals and growth regulators on post-harvest quality and shelf life of jackfruit (*Artocarpus heterophyllus* L.) *cv.* Palur -1 flakes

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Abstract
An experiment was carried out during the rabi season, 2021-2022, at Horticultural Research Station, Venkataramannagudem, West Godavari District, Andhra Pradesh. The experiment was laid in Randomized Block Design with 12 treatments with three replications. The fruits of jackfruit were sprayed with different plant growth regulators *viz*., GA_3 50 ppm (T_1), GA_3 100 ppm (T_2), 6-BAP 50 ppm (T_3), 6-BAP 100 ppm (T_4), NAA 50 ppm (T_5), NAA 100 ppm (T_6) and chemicals *viz*., $CaCl_2$ @ 1% (T_7), $CaCl_2$ @ 2% (T_8), Ca $(NO_3)_2$ @ 1% (T_9), Ca $(NO_3)_2$ @ 2% (T_{10}) and control (Water spray) T_{11}, (No spray) T_{12} at 90 and 115 days after fruit set. After harvesting of fruits, flakes were pre-treated with 0.25% ascorbic acid and packed in 200 gauge polypropylene bag and then stored at refrigerator condition (3±1 ^{0}C). The results revealed that pre-harvest application of $CaCl_2$ 2% (T_8) or GA_3 50 ppm (T_1) was found to be effective for increasing total soluble solids, total sugar, reducing sugar, non-reducing sugar, ascorbic acid, β- carotene content, pectin content, calcium content, protein content, antioxidant activity, shelf life and overall acceptability with minimum physiological loss in weight, decay loss, titratable acidity, the fibre content of jackfruit flakes at different days of storage.

Keywords: Jackfruit flakes, growth regulators, chemicals, $CaCl_2$, GA_3

Introduction
The jackfruit tree (*Artocarpus heterophyllus* L.) 2n = 4X = 56 (Tetraploid) belongs to the family Moraceae and is a fairly large-sized tree bearing the largest fruit among edible known fruits. It is a monoecious evergreen latex-producing tree, up to 20m in height, with dark green entire leaves. The fruits are pear or barrel-shaped, borne on a 5-10cm stalk; the thick skin has short protuberances, fleshy, golden yellow, edible perianth that surrounds the seed and the seed is surrounded by a horny endocarp and sub gelatinous exocarp. Jackfruit is native to India and is mainly found in tropical Asian countries like India, Sri Lanka, Bangladesh, Indonesia, Malaysia and the Philippines. Jackfruit is quite popular in Eastern and Southern India and cultivated widely in Kerala, Karnataka, Andhra Pradesh, Tamil Nadu, West Bengal, Maharashtra, Assam and Andaman and the Nicobar Islands and Andhra Pradesh, primarily grown in Visakhapatnam, Vijayanagaram and Godavari districts.
Jackfruit is rich in vitamins (A and B) and minerals (Ca, K, Mg and Fe) and contains considerable amounts of carotene. Vitamin C. Fruit is highly fibrous and has nutritive value, containing 18.9g carbohydrates, 0.8g minerals, 30IU vitamin-A and 0.25mg thiamine for every hundred grams (Samaddar, 1985) [21]. For this reason, it is commonly referred to as "Poor man's food". The energy available to humans in jackfruit has been estimated to be 2 MJ per Kg of the wet ripe perianth (Ahmed *et al.* 1986) [1]. Ripe fruit flakes are rich in nutritive value; it contains 11-19g of carbohydrates, 30.0-73.2mg calcium and 287-323mg of potassium per 100g of ripe flakes (Elevitch and Manner, 2006) [20]. Jackfruit seeds can be used in many culinary preparations as boiled or roasted items. The pulp can also be prepared pickles, chips, de-hydrated leather and thin Papads. The seed is a rich source of protein, and major protein has been extracted as "Jacalin".
Jackfruit is a climacteric fruit having a high degree of perishability. It ripens within a few days after harvesting and shows less shelf life at ambient temperature. Thus, ripe fruits become unfit for consumption within 2-3 days.

An average consumer prefers to eat 2-5 bulbs at a time; hence the tendency of consumers is to purchase loose bulbs instead of single whole fruit at a time. Therefore, various chemicals and plant growth regulators have been used to decrease physiological loss and post-harvest losses and to improve or maintain the colour and quality by slowing down the metabolic activity of the fruit and increasing the shelf life by delaying ripening increase in firmness, reducing respiration.

To minimize the post-harvest losses and extend the shelf life of jackfruit bulbs, the provision of chemical treatment for bulbs is necessary. This will help to provide fresh bulbs in the hands of consumers. Post-harvest chemicals like Potassium metabisulphite (KMS), citric acid, calcium chloride, and ascorbic acid helps to extend the shelf life of fruits. Therefore, the present investigation was carried out to assess the response of preharvest spray of chemicals and plant growth regulators to quality attributes and shelf life of jackfruit flakes.

Materials and Methods

An experiment was carried out during the rabi season, 2021-2022, at Horticultural Research Station, Venkataramannagudem, West Godavari District, Andhra Pradesh. The experiment was laid in Randomized Block Design with 12 treatments with three replications. The fruits of jackfruit were sprayed with different plant growth regulators *viz*., GA_3 @ 50 ppm (T_1), GA_3 @ 100 ppm (T_2), 6-BAP @ 50 ppm (T_3), 6-BAP @ 100 ppm (T_4), NAA @ 50 ppm (T_5), NAA @ 100 ppm (T_6) and chemicals *viz*., $CaCl_2$ @ 1% (T_7), $CaCl_2$ @ 2% (T_8), Ca $(NO_3)_2$ @ 1% (T_9), Ca $(NO_3)_2$ @ 2% (T_{10}) and control (Water spray) T_{11}, (No spray) T_{12} at 90 and 115 days after fruit set and flakes were pre-treated with 0.25% ascorbic acid and then stored at refrigerator condition (3±1 ^{0}C). The jackfruit fruits were assessed on the 3rd, 6th, 9th and 12th day of storage for TSS, acidity, total sugar, reducing sugar, non-reducing sugar, ascorbic acid, ripening index, physiological loss in weight, decay loss, pectin content, protein content, β-carotene, fibre content, antioxidant activity and calcium content.

Results and Discussion

The data on the physiological loss in weight (%) of jackfruit flakes are shown in Table 1. During the 3rd day of the storage period, significant lowest physiological loss in weight (%) was recorded in all treatments, including control, *i.e.,* less than 10%. On the 3rd, 6th, 9th and 12th day of the storage period, the lowest physiological loss in weight (%) of jackfruit flakes (2.27%, 5.72%, 9.14% and 14.76%) was recorded in pre harvest application of $CaCl_2$ @ 2% (T_8), which was on par with treatment (T_1) GA_3 @ 50 ppm, *i.e.,* 2.48%, 5.97%, 9.58% and 15.02% respectively. Calcium is a constituent of pectate; it might have made the middle lamella of fruit cell wall thicker by increased deposition of calcium thus, maintaining the fruit firmness and reducing physiological weight loss (%). The results obtained were similar to the findings of Singh *et al*. (2012) [17] in mango, Pisutpiboonwong (2017) [14], Bagul and Masu (2017) [3] in custard apple, Kour *et al*. (2017) [10] in litchi, and Anusuya *et al.* (2019) [2] in sapota.

In the treatment (T_8) $CaCl_2$ @ 2%, Total soluble solids (Table 2) increased initially up to the 9th day of the storage period and declined until the end of storage. Pre harvest spray of $CaCl_2$ @ 2% (T_8) recorded the maximum TSS (23.9, 25.5, 26.4, 25.1^0 Brix) which was found on par with treatment T_1 (GA_3@ 50 ppm) *i.e.*, 22.9, 24.9, 25.7, 24.5^0 Brix) respectively at all the storage period. TSS increased up to 9 days due to the breakdown of complex polymers (starch) into simple substances (sugars) by hydrolytic enzymes. Similar findings have been reported by Bhalerao *et al.* (2009) [4] in sapota, Yadav *et al.* (2009) [18] in ber, Karemera, and Habimana (2014) [8] in mango, Kirmani *et al.* (2015) [9] in plum, and Patel *et al.* (2017) [12] in Sapota.

The data on the titratable acidity (%) of jackfruit flakes are shown in table 3. Pre harvest application of $CaCl_2$ @ 2% recorded the lowest titratable acidity content (%) in jackfruit flakes (0.26%, 0.23% and 0.22%) at all the storage periods respectively, which was on par with treatment GA_3 @ 50 ppm (T_1), *i.e.,* (0.27%, 0.24% and 0.23%) respectively. The decline in acidity may be due to the conversion of carbohydrates to sugar. The present investigation on acidity is similar to results reported by Bhalerao *et al.* (2010) [4], Jayachandran *et al.* (2005) [7], Yadav *et al.* (2009) [18] in ber, Karemera *et al.* (2014) [8] and Bagul (2016) [16] in custard apple.

Data (Table 4) on ascorbic acid revealed that the highest ascorbic acid content (%) in jackfruit flakes (46.37, 45.32, 43.62 and 40.46 mg/100 gm pulp) was recorded in pre harvest application of $CaCl_2$ @ 2% (T_8), which was on par with treatment GA_3 @ 50 ppm (T_1) (45.38, 44.75, 42.97 and 39.68 mg/100 gm pulp) respectively at 3rd, 6th, 9th and 12th day of the storage period. During the entire storage period, the gradual reduction in ascorbic acid content might be due to its degradation through enzymatic oxidation of L-ascorbic acid to dehydroascorbic acid during metabolic processes. The present investigation is similar to results reported by Yadav *et al.* (2009) [18] in ber, Rajput *et al.* (2008) [15], Bisen *et al.* (2014) [5] in guava and Bagul (2016) [16] in custard apple.

β-carotene (Table 5) increased initially up to the 9th day of the storage period and declined until the end of storage. Pre harvest spray of $Cacl_2$ @ 2% treatment recorded the highest β-carotene content (1.39, 1.58 and 1.74 mg/100 gm) followed by GA_3 @ 50 ppm (T_1) (1.33, 1.54 and 1.69 mg/100 gm) than both the control treatments at all the storage periods. As the storage period increases, a significant decrease in β- carotene is due to non-oxidative changes (cis-trans isomerization, epoxide formation or heat degradation of tissue) or oxidative changes. The present investigation on β-carotene is similar to results reported by Navjot (2006) [11] in peach.

The data about pectin content (%) of jackfruit flakes which were kept for storage presented in table 6. The pectin content was decreased from the 3rd day to 12th day during the storage period. On 3rd day and 6th day of the storage period, significant highest pectin content (2.01% &1.94%) was recorded in pre harvest application of $CaCl_2$ @ 2% (T_8) which was on par with T_1 (GA_3 @ 50 ppm) *i.e.,*1.96% & 1.89% and T_7 ($CaCl_2$ @ 1%) *i.e.,*1.95% and 1.89% respectively. This might be due to the decrease in protopectin and methoxyl content with decreasing firmness of the fruit and also due to enzymatic degradation of pectin. Jayachandran *et al.* (2005) [7] and Rajput *et al.* (2008) [15] reported similar results on the retention of pectin.

The data relating to protein content (%) of the seed of stored jackfruit flakes were presented in table 7. The data revealed a significant difference among all treatments during storage. Pre harvest spray of $CaCl_2$ @ 2% (T_8) recorded the highest protein content (3.51%) followed by treatment T_1 (GA_3 @ 50 ppm) with 3.31% compared to control (T_{11} and T_{12}) *i.e.,* 0.93% and 0.83%. The protein content of the seed was decreased from the initial day to the 12th day during the storage period. There was a significant decrease in protein content during the storage period due to the denaturation and degradation of protein into amino acids (Parimita & Arora 2015) [13]. A similar decline has been reported by Chorage *et al.* (2020) [6] in guava jam.

Table 1: Effect of pre-harvest sprays of chemicals and growth regulators on physiological loss in weight (%) of jackfruit flakes during storage

Treatment	Treatment details	3 days	6 days	9 days	12 days	Mean
T_1	GA_3 @ 50 ppm	2.48	5.97	9.58	15.02	8.26
T_2	GA_3 @ 100 ppm	4.47	8.31	12.63	18.59	11.00
T_3	6 BAP @ 50 ppm	7.28	14.45	22.15	30.15	18.51
T_4	6 BAP @ 100 ppm	7.49	14.91	22.97	31.47	19.21
T_5	NAA @ 50 ppm	3.16	7.48	12.36	19.68	10.67
T_6	NAA @ 100 ppm	5.12	9.39	14.73	21.58	12.71
T_7	$CaCl_2$ @ 1%	3.1	7.17	11.68	17.42	9.84
T_8	$CaCl_2$ @ 2%	2.27	5.72	9.14	14.76	7.97
T_9	$Ca(NO_3)_2$ @ 1%	4.56	8.45	13.21	19.53	11.44
T_{10}	$Ca(NO_3)_2$ @ 2%	5.52	9.38	15.02	22.47	13.10
T_{11}	Water spray	6.36	12.54	19.46	27.83	16.55
T_{12}	No spray	6.47	12.78	19.83	28.34	16.86
CD @ 5%		0.282	0.468	0.668	0.942	
S.Em ±		0.096	0.159	0.226	0.319	

Table 2: Effect of pre-harvest sprays of chemicals and growth regulators on Total soluble solids (ºBrix) of jackfruit flakes during storage

Treatment	Treatment details	3 days	6 days	9 days	12 days	Mean
T_1	GA_3 @ 50 ppm	22.9	24.9	25.7	24.5	24.5
T_2	GA_3 @ 100 ppm	22.8	23.7	22.9	20.8	22.6
T_3	6 BAP @ 50 ppm	20.6	20.1	19.3	17.5	19.4
T_4	6 BAP @ 100 ppm	20.1	19.9	18.8	16.1	18.7
T_5	NAA @ 50 ppm	22.6	23.8	22.3	20.5	22.3
T_6	NAA @ 100 ppm	21.7	22.9	21.1	19.8	21.4
T_7	$CaCl_2$ @ 1%	21.5	22.6	21.2	20.3	21.4
T_8	$CaCl_2$ @ 2%	23.9	25.5	26.4	25.1	25.2
T_9	$Ca(NO_3)_2$ @ 1%	22.5	23.5	22.3	20.6	22.2
T_{10}	$Ca(NO_3)_2$ @ 2%	22.2	23.8	21.8	19.7	21.9
T_{11}	Water spray	21.4	20.4	19.5	17.7	19.8
T_{12}	No spray	21.1	20.2	19.1	17.2	19.4
C.D @ 5%		1.15	0.903	0.89	0.875	
S.Em ±		0.39	0.306	0.301	0.296	

Table 3: Effect of pre-harvest sprays of chemicals and growth regulators on Titratable acidity (%) of jackfruit flakes during storage

Treatment	Treatment details	3 days	6 days	9 days	12 days	Mean
T_1	GA_3 @ 50 ppm	0.27	0.24	0.23	0.21	0.24
T_2	GA_3 @ 100 ppm	0.28	0.25	0.24	0.21	0.25
T_3	6 BAP @ 50 ppm	0.37	0.36	0.34	0.33	0.35
T_4	6 BAP @ 100 ppm	0.39	0.37	0.35	0.34	0.36
T_5	NAA @ 50 ppm	0.28	0.25	0.24	0.22	0.25
T_6	NAA @ 100 ppm	0.29	0.28	0.27	0.25	0.27
T_7	$CaCl_2$ @ 1%	0.27	0.24	0.23	0.21	0.24
T_8	$CaCl_2$ @ 2%	0.26	0.23	0.22	0.19	0.23
T_9	$Ca(NO_3)_2$ @ 1%	0.29	0.27	0.26	0.24	0.27
T_{10}	$Ca(NO_3)_2$ @ 2%	0.29	0.28	0.27	0.26	0.28
T_{11}	Water spray	0.30	0.28	0.28	0.27	0.28
T_{12}	No spray	0.32	0.29	0.28	0.28	0.29
C.D @ 5%		0.016	0.014	0.014	0.012	
S.Em ±		0.005	0.005	0.005	0.004	

Table 4: Effect of pre-harvest sprays of chemicals and growth regulators on Ascorbic acid (mg/ 100gm pulp) of jackfruit flakes during storage

Treatment	Treatment details	3 days	6 days	9 days	12 days	Mean
T_1	GA_3 @ 50 ppm	45.38	44.75	42.97	39.68	43.20
T_2	GA_3 @ 100 ppm	43.61	41.76	38.26	33.52	39.29
T_3	6 BAP @ 50 ppm	20.47	17.36	13.78	8.26	14.97
T_4	6 BAP @ 100 ppm	14.78	11.64	9.17	6.45	10.51
T_5	NAA @ 50 ppm	43.84	42.19	39.47	34.68	40.05
T_6	NAA @ 100 ppm	41.95	39.36	35.79	30.52	36.91
T_7	$CaCl_2$ @ 1%	44.56	42.47	39.52	34.03	40.15

T_8	$CaCl_2$ @ 2%	46.37	45.32	43.62	40.46	43.94
T_9	Ca $(NO_3)_2$ @ 1%	42.01	40.96	37.83	34.01	38.70
T_{10}	Ca $(NO_3)_2$ @ 2%	41.74	39.47	34.68	28.62	36.13
T_{11}	Water spray	26.98	23.45	19.56	14.79	21.20
T_{12}	No spray	25.87	22.47	18.98	14.03	20.34
C.D @ 5%		1.742	1.402	1.35	1.454	
S.Em ±		0.59	0.475	0.457	0.493	

Table 5: Effect of pre-harvest sprays of chemicals and growth regulators on β - Carotene (mg/100 gm) of jackfruit flakes during storage

Treatment	Treatment details	3 days	6 days	9 days	12 days	Mean
T_1	GA_3 @ 50 ppm	1.33	1.54	1.69	1.24	1.45
T_2	GA_3 @ 100 ppm	1.18	1.40	1.32	1.03	1.23
T_3	6 BAP @ 50 ppm	0.89	0.82	0.74	0.62	0.77
T_4	6 BAP @ 100 ppm	0.85	0.78	0.61	0.48	0.68
T_5	NAA @ 50 ppm	1.31	1.38	1.29	1.19	1.29
T_6	NAA @ 100 ppm	0.98	1.08	1.02	0.98	1.02
T_7	$CaCl_2$ @ 1%	1.28	1.47	1.21	1.03	1.25
T_8	$CaCl_2$ @ 2%	1.39	1.58	1.74	1.34	1.51
T_9	Ca $(NO_3)_2$ @ 1%	1.15	1.49	1.38	1.12	1.29
T_{10}	Ca $(NO_3)_2$ @ 2%	1.11	1.31	1.03	0.83	1.07
T_{11}	Water spray	0.98	0.89	0.71	0.54	0.78
T_{12}	No spray	0.93	0.87	0.64	0.51	0.74
C.D @ 5%		0.074	0.063	0.055	0.043	
S.Em ±		0.025	0.021	0.019	0.015	

Table 6: Effect of pre-harvest sprays of chemicals and growth regulators on Pectin content (%) of jackfruit flakes during storage

Treatment	Treatment details	3 days	6 days	9 days	12 days	Mean
T_1	GA_3 @ 50 ppm	1.96	1.89	1.76	1.59	1.80
T_2	GA_3 @ 100 ppm	1.89	1.82	1.64	1.29	1.66
T_3	6 BAP @ 50 ppm	1.49	1.16	0.87	0.64	1.04
T_4	6 BAP @ 100 ppm	1.38	1.03	0.72	0.58	0.93
T_5	NAA @ 50 ppm	1.87	1.81	1.60	1.27	1.64
T_6	NAA @ 100 ppm	1.91	1.84	1.56	1.21	1.63
T_7	$CaCl_2$ @ 1%	1.95	1.89	1.65	1.30	1.70
T_8	$CaCl_2$ @ 2%	2.01	1.94	1.83	1.67	1.86
T_9	Ca $(NO_3)_2$ @ 1%	1.89	1.82	1.61	1.29	1.65
T_{10}	Ca $(NO_3)_2$ @ 2%	1.87	1.72	1.56	1.14	1.57
T_{11}	Water spray	1.63	1.36	0.95	0.72	1.17
T_{12}	No spray	1.58	1.31	0.91	0.69	1.12
C.D @ 5%		0.093	0.078	0.065	0.069	
S.Em ±		0.032	0.027	0.022	0.024	

Table 7: Effect of pre-harvest sprays of chemicals and growth regulators on Protein content (%) of jackfruit flakes during storage

Treatment	Treatment details	3 days	6 days	9 days	12 days	Mean
T_1	GA_3 @ 50 ppm	3.53	3.46	3.27	2.98	3.31
T_2	GA_3 @ 100 ppm	2.96	2.82	2.68	2.36	2.71
T_3	6 BAP @ 50 ppm	1.01	0.86	0.64	0.42	0.73
T_4	6 BAP @ 100 ppm	0.98	0.72	0.52	0.34	0.64
T_5	NAA @ 50 ppm	2.90	2.81	2.57	2.26	2.64
T_6	NAA @ 100 ppm	2.16	2.01	1.89	1.67	1.93
T_7	$CaCl_2$ @ 1%	3.15	3.01	2.82	2.61	2.90
T_8	$CaCl_2$ @ 2%	3.77	3.62	3.45	3.18	3.51
T_9	Ca $(NO_3)_2$ @ 1%	2.89	2.76	2.52	2.18	2.59
T_{10}	Ca $(NO_3)_2$ @ 2%	2.29	2.13	1.98	1.82	2.06
T_{11}	Water spray	1.19	1.04	0.86	0.62	0.93
T_{12}	No spray	1.05	0.93	0.76	0.58	0.83
C.D @ 5%		0.122	0.119	0.103	0.093	
S.Em ±		0.041	0.04	0.035	0.032	

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