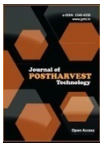

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RESEARCH ARTICLE

Impact of chemicals and modified atmosphere packaging (MAP) on postharvest quality of litchi cv. China

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ABSTRACT

The efficacy of chemicals and modified atmosphere packaging were investigated in freshly harvested litchi fruit to observe the bio-chemical changes and extension of shelf life of fruits at two days interval for a period of six days storage at ambient temperature during 2020-2021, Department of Horticulture, SASRD, Nagaland University. The pre-cooled litchi fruits after disinfectant were emerged in $CaCl_2$ (1% & 2%), Wax emulsion (5% & 10%), Chitosan (1% & 2%) and Kaolin (1% & 2%) for 60 seconds. The treated fruits were packed in polypropylene plastic (PPP) @ 6% and 9% perforation and assessed the quality attributes at two days interval. The fruits dipped in calcium chloride solution @ 1% and 2% and wax emulsion @ 5% and also packed in polypropylene plastic @ 6% perforation showed a positive and significant impact to maintain biochemical quality during storage. The fruits treated with calcium chloride @ 1% packed in 6% perforation polypropylene plastic recorded maximum total soluble solids (17.62°B), total sugar (11.36%), ascorbic acid (54.48 mg/100g pulp), fruit firmness (1.90 kg cm^{-2}), polymeric colour retention with high anthocyanin content (49.67 mg/100g peel) in peel and the lowest acidity (0.48%) in juice at 6 days of storage.

Keywords: Litchi, chemicals, MAP, quality, storage

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INTRODUCTION

Litchi (*Litchi chinensis* Sonn.) is a sub-tropical evergreen fruit crop that belongs to family sapindaceae and originated in China, where it has been grown in Southern Guangdong State for thousands of years. It is a highly specific climatic requirement crop and probably because of the fact, its cultivation is restricted to few countries in the world. At present, in India 711.0 thousand metric tonnes of litchi is produced annually from 93.00 thousand hectares' area (Anon., 2019). In India, litchi occupies the 7th ranks in area and 9th in production among fruit crops but in value terms, it ranks sixth. Although India is the second largest producer of litchi after China and about 95% of litchi production of the world is in south-east Asia. But a widespread post harvest challenges for shelf life extension is the biggest barrier for ambitious vendors involved in trade of litchi fruits that deteriorates very fast after harvest. Freshness or quality maintenance right after harvest of litchi has been one of the biggest challenges in litchi supply chain (Singh et al., 2012). The existing gaps in yield potential, production of poor quality, un-attractive cracked and sunburn fruits (Sarkar et al., 2020; Sumi and Sarkar, 2020; Mitra et al., 2010) and negligible export potential of quality litchi fruit are the main concerns. These needs to be combated in modern day fruit production to meet the

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ever increasing demand to nourish the growing population and increasing the economic returns. Litchi is a non-climacteric fruit and as such does not ripe once after harvest. The respiration rate of the fruit decreased progressively during fruit development with immature fruitlets having 8 to 10 times greater than that of the mature fruit. Respiration and ethylene production can be significantly reduced using low temperatures (5 °C) but they increase rapidly above that at harvest, when transferred to 25 °C (Jiang-Ping et al., 1986). A steady process of moisture loss (dehydration), micro-cracking, pericarp browning and decay are the post harvest challenges that limit the fruit quality during storage and transportation (Sumi et al., 2021; Tian et al., 2005; Sivakumar et al., 2007). Although browning of pericarp does not affect so much the sensory quality of litchi fruit (Mangaraj and Goswami, 2011) but influence the consumers preference and mindset to purchase the fruit with premium cost. Techniques to reduce browning and maintain the red colour and prolonged storage life includes chemical treatments, packaging in perforated plastic bags and storage under cold conditions was confirmed by Neog and Saikia, 2010; Mphahlele et al., 2020. The technology developed offers a practical solution to the difficulties associated with litchi. Modified atmosphere packaging, shrink wrap and vacuum packaging have been widely adopted to maintain quality and fresh litchi fruit during prolonged storage (Sivakumar and Korsten, 2006a,b). Controlled atmosphere storage and packaging is leads better maintenance of the freshness of the fruits during transportation. Thus, to obtain better post-harvest shelf life of fruits, careful harvesting, pre-cooling, transportation in cool van, and maintenance of temperature (2-3°C) would be efficient measures. Keeping in view the commercial importance and potential of litchi in Nagaland, the research efforts had been intensified to get fruits with superior quality and extension of shelf life by influencing of chemicals and modified atmospheric packaging (MAP) on post harvest quality of fruits.

MATERIALS AND METHODS

The present laboratory experiment was conducted in Department of Horticulture, Nagaland University, SASRD, Medziphema Campus during 2020-2021. Fully matured uniform ripen fruits were randomly harvested from each direction of canopy at early morning attached to the pedicel to maintain the keeping quality. Right after harvest, the fruits were placed in ice water for pre-cooling and fan dried thereof. The fruits were dipped in chemical solutions of different concentrations for 60 seconds. The treated fruits were packed in polypropylene plastic (PPP) @ 6% and 9% perforation and assessed the quality attributes at two days interval. The treatments comprised of T_1: $CaCl_2$ @ 1% + PPP @ 6% perforation, T_2: $CaCl_2$ @ 1%+ PPP @ 9% perforation, T_3: $CaCl_2$ @ 2% + PPP @ 6% perforation, T_4: $CaCl_2$ @ 2%+ PPP @ 9% perforation, T_5: Wax emulsion @ 5%+ PPP @ 6% perforation, T_6: Wax emulsion @ 5%+ PPP @ 9% perforation, T_7: Wax emulsion @ 10%+ PPP @ 6% perforation, T_8: Wax emulsion @ 10%+ PPP @ 9% perforation, T_9: Chitosan @ 1%+ PPP @ 6% perforation, T_{10}: Chitosan @ 1%+ PPP @ 9% perforation, T_{11}: Chitosan @ 2%+ PPP @ 6% perforation, T_{12}: Chitosan @ 2%+ PPP @ 9% perforation T_{13}: Kaolin @ 1% + PPP @ 6% perforation, T_{14}: Kaolin @ 1%+ PPP @ 9% perforation,T_{15}: Kaolin @ 2% + PPP @ 6% perforation,T_{16}: Kaolin @ 2% + PPP @ 9% perforation, T_{17}: Control. The experiment was laid out in Completely Randomized Design (CRD) and all the treatments were represented by three replicates. Observations were recorded at 0, 2, 4 and 6 days after harvest (DAH) for TSS, total sugar, titratable acidity, Vitamin-C, anthocyanin and firmness. The TSS of fruit was determined with the help of EMRA hand refractometer (0-32 ^{0}Brix) calibrated at 20 ^{0}C and the result were expressed in Brix (^{0}B). Total sugar content of the fruit was estimated by titrating the fruit juice against Fehling ‘A’ and Fehling ‘B’ reagents using methylene blue as indicator and presented in percent (%). Titratable acidity was estimated by titrating the diluted fruit juice against 0.1N NaOH solution using phenolphthalein as an indicator and expressed in term of percentage fresh weight of fruit (Ranganna, 2001). Ascorbic acid content was estimated by visual titration method of 2, 6 Dichlorophenol Indophenols dye as suggested by A.O.A.C. (1984) and expressed in mg/100 g of juice. Anthocyanin content of peel was estimated by standard procedure of Ranganna, 2001 and expressed as mg/100g of peel. The fruit firmness was measured by using penetrometer and expressed in kg cm^{-2}.

RESULTS AND DISCUSSION

Total soluble solids (TSS)

The litchi fruits treated with different chemicals and packed in 6% and 9% perforation polypropylene plastic were found to have significant influence on TSS in progress of storage duration as shown in Table 1. A general increasing trend in TSS content of fruits was noticed in respect of various chemical treatments (average 14.79±0.03^{0}B at 0 DAH and 16.82±0.17^{0}B at 6 DAH). Initial TSS range (14.46 to 15.05 ^{0}B) of freshly harvested fruits did not show significant variation but at end of storage (6 DAH), a significant variation ranging between 16.11 and 17.62^{0}B was clearly noticed under different treatments. Calcium chloride treated fruits @ 1% and 2% showed the significant increase in TSS (17.51-17.62°B) content in fruits packed with PPP @ 6% perforation under room temperature at 6 DAH and the lowest was obtained from chitosan @ 2% as 16.11°B at 6 DAH. Wax emulsion @ 5% + PPP @ 6% perforation also played a significant role to interweave in TSS maintenance (17.14^{0}B) during storage of fruits. The results also indicated that packaging in perforation polypropylene plastic have marked influence on TSS content of the fruit during storage. Here, the mean value of initial TSS (14.79 ^{0}B at 0 DAH) and end of storage (16.82 ^{0}B at 6 DAH) clearly indicated that chemicals and modified atmospheric packaging (MAP) had a marked and significant influence in TSS of fruits (p=4.23129E-13). Hydrolysis of starch or conversion of acids into sugars could be the reason for the increase in TSS with advancement of storage period reported by Wills et al. (1996). Higher level of TSS in fruits was retained by 1% calcium chloride treated fruits during storage. It may be due to the role of calcium salts in maintaining the lowest metabolic activity during storage of fruits and hydrolysis of starch or conversion of acids to sugar (Aklimuzzaman et al., 2011). The results are also in agreement with those of Almenar et al. (2008) in blueberry, Srinu et al. (2017) in papaya, Singh et al. (2017) in litchi and Sumi et al. (2021) in litchi cv. China by using calcium treatments under perforated polythene bags to maintain the TSS consistency and extension of post harvest shelf of fruits during storage.

Total sugar

The total sugar contents of fruit as depicted in Table 1 showed that different concentration of chemicals and fruits packed in perforation polypropylene plastic have a significant effect in total sugar content of fruits during progress of storage (except at 0 DAH). A general increasing trend in total sugar content of fruits was noticed from initial to end of storage under different treatments (average 8.90±0.02% at 0 DAH and 10.63±0.19% at 6 DAH). At initial stage, there was no significant impact in total sugar content (8.70 to 9.07%) of freshly harvested fruits but at end of storage (6 DAH) showed a positive and significant variation (10.29 to 11.36%). The maximum total sugar (11.24 to 11.36%) was recorded in fruits treated with calcium chloride @1% and 2% + PPP @ 6% perforation in room temperature at 6 DAH and the lowest was noted in Chitosan @ 1% (9.84%) and 2% (9.86%) at PPP @ 9% perforation and untreated control (10.32%). Wax emulsion in both @ 5% and 10% in PPP @ 6% perforation also played a significant role to maintain in total sugar content (11.05-11.07%) during storage of fruits. Here, the mean value of total sugar at initial (8.90% at 0 DAH) and end of storage (10.63% at 6 DAH) clearly indicated that chemicals and modified atmospheric packaging (MAP) with polypropylene plastic had a marked and significant influence in total sugar content of fruits (p=9.08E-11). Increase in total sugar during storage might be due to breakdown of polysaccharides into monosaccharides and disaccharides or due to conversion of starch into sugars. Higher sugar level was retained by 1% calcium chloride treated fruits during storage which may be due to the role of calcium chloride to delay senescence. These results were in close conformity with the findings of Mahfuzah et al. (2013) using 1% calcium chloride stored at 10 °C in strawberry fruits and Sharma et al. (2015) in apple using 0.25% calcium chloride. Shailaja et al. (2015) also reported highest total sugar in custard apple using polypropylene bags with maximum pores (60 pores).

Table 1. Influence of chemicals and MAP on total soluble solids, total sugar and titratable acidity in litchi cv. China

Treatments	TSS (°B)				Total sugar (%)				Titratable acidity (%)			
	0 DAH	2 DAH	4 DAH	6 DAH	0 DAH	2 DAH	4 DAH	6 DAH	0 DAH	2 DAH	4 DAH	6 DAH
T_1	15.05	16.61	17.34	17.62	9.07	10.68	11.15	11.36	0.69	0.60	0.55	0.48
T_2	14.87	16.22	16.85	17.07	8.75	10.21	10.53	10.72	0.68	0.65	0.62	0.57
T_3	14.65	16.30	17.15	17.51	8.70	10.48	10.91	11.24	0.72	0.69	0.62	0.49
T_4	14.46	15.92	16.67	16.89	9.00	10.02	10.33	10.62	0.77	0.65	0.64	0.61
T_5	14.87	16.43	17.19	17.14	8.70	10.55	10.95	11.07	0.68	0.67	0.58	0.54
T_6	14.65	16.04	16.73	16.63	8.79	10.10	10.42	10.50	0.72	0.68	0.64	0.60
T_7	15.05	16.50	17.21	17.10	9.00	10.60	11.00	11.05	0.62	0.67	0.62	0.55
T_8	14.46	16.12	16.77	16.60	8.79	10.12	10.42	10.43	0.77	0.67	0.67	0.62
T_9	15.00	15.64	16.53	16.73	8.70	9.95	10.40	10.58	0.63	0.74	0.64	0.61
T_{10}	14.77	15.05	15.90	16.11	9.07	9.39	9.68	9.84	0.69	0.77	0.69	0.72
T_{11}	14.87	15.72	16.56	16.75	8.75	9.98	10.40	10.61	0.68	0.68	0.67	0.60
T_{12}	14.77	15.19	15.92	16.16	8.79	9.43	9.68	9.86	0.69	0.74	0.75	0.73
T_{13}	15.00	16.09	16.87	17.04	9.00	10.25	10.76	10.97	0.63	0.64	0.59	0.58
T_{14}	14.65	15.62	16.31	16.46	9.07	9.79	10.05	10.29	0.72	0.76	0.69	0.65
T_{15}	14.77	16.12	16.92	17.05	9.00	10.30	10.80	11.00	0.69	0.66	0.59	0.57
T_{16}	14.77	15.67	16.35	16.53	9.07	9.82	10.10	10.33	0.69	0.71	0.75	0.64
T_{17}	14.82	15.50	16.34	16.55	9.00	9.79	10.13	10.32	0.65	0.71	0.71	0.64
Mean	14.79	15.93	16.68	16.82	8.90	10.09	10.45	10.63	0.69	0.69	0.65	0.60
CD at 5%	NS	NS	0.72	0.79	NS	NS	0.76	0.71	0.04	NS	0.12	0.12

T_1: $CaCl_2$ @ 1% + PPP @ 6% perforation, **T_2**: $CaCl_2$ @ 1%+ PPP @ 9% perforation, **T_3**: $CaCl_2$ @ 2% + PPP @ 6% perforation, **T_4**: $CaCl_2$ @ 2%+ PPP @ 9% perforation, **T_5**: Wax emulsion @ 5%+ PPP @ 6% perforation, **T_6**: Wax emulsion @ 5%+ PPP @ 9% perforation, **T_7**: Wax emulsion @ 10%+ PPP @ 6% perforation, **T_8**: Wax emulsion @ 10%+ PPP @ 9% perforation, **T_9**: Chitosan @ 1%+ PPP @ 6% perforation, **T_{10}**: Chitosan @ 1%+ PPP @ 9% perforation, **T_{11}**: Chitosan @ 2%+ PPP @ 6% perforation, **T_{12}**: Chitosan @ 2%+ PPP @ 9% perforation **T_{13}**: Kaolin @ 1% + PPP @ 6% perforation, **T_{14}:** Kaolin @ 1%+ PPP @ 9% perforation, **T_{15}:** Kaolin @ 2% + PPP @ 6% perforation, **T_{16}:** Kaolin @ 2% + PPP @ 9% perforation, **T_{17}:** Control

Titratable acidity (TA)

Titratable acidity was significantly influenced by storage duration depicted in Table 1 and 2. At 0 DAH, titratable acidity was 0.69% and then decreased gradually with storge duration progress. A significant decline (p=0.0001914) in acidity by approximately 13.04% reduction from initial to end of storage was noted. But in some treatments TA level behaved absurd at 0 DAH to 2 DAH by increasing the amount of acidity and again declined gradually. It was observed that fruits treated with calcium chloride @ 1% and 2% and wax emulsion @ 5% and 10% packed in PPP @ 6% perforation level showed minimum level of acidity (0.48 to 0.55% at 6 DAH) at end of storage. The level of acidity was found to be maximum in fruits treated with chitosan packed in PPP @ 9% perforation level (0.72-0.73%). A general declining trend in acid content was noticed in various perforation of packaging where the lowest acid content was recorded by PPP @ 6% perforation and highest acidity was by PPP @ 9% perforation. The data indicated that the gradual decrease in acidity under all the treatments during storage might be due to utilization of acid in metabolism. This gradual decrease in acidity with increase in storage period could be attributed to use of rapid utilization of organic acids in the respiratory and the bioconversion of acids into sugars or it could be attributed to the chemical interaction between the organic constituents of the juice induced by temperature and the action of enzymes (particularly invertase). A significant decline in acidity with advancement of storage period in China variety by Sumi et al.

(2021), Huaizhi variety by Dong et al. (2004), Mauritius variety by Mphahlele et al. (2020) and Ghosh et al. (1998) in litchi were reported.

Table 2. Influence of chemicals and MAP on ascorbic acid, anthocyanin and fruit firmness in litchi cv. China

Treatments	Ascorbic acid (mg/100g pulp)				Anthocyanin (mg/100g peel)				Firmness (kg cm^{-2})			
	0 DAH	2 DAH	4 DAH	6 DAH	0 DAH	2 DAH	4 DAH	6 DAH	0 DAH	2 DAH	4 DAH	6 DAH
T_1	60.67	59.28	57.33	54.48	51.55	50.10	49.87	49.67	2.14	2.00	1.97	1.90
T_2	62.00	54.67	52.00	48.00	51.00	49.82	49.46	49.12	2.07	1.73	1.71	1.62
T_3	65.67	58.25	56.27	53.93	51.13	49.93	49.73	49.28	2.12	1.95	1.89	1.82
T_4	65.00	53.78	50.87	47.00	50.25	49.66	49.30	48.77	2.02	1.65	1.58	1.49
T_5	62.00	58.67	56.67	52.53	50.81	50.58	50.38	49.57	2.05	2.02	1.93	1.85
T_6	60.67	54.11	51.23	46.00	50.25	50.23	49.93	49.05	2.07	1.76	1.66	1.55
T_7	65.67	58.90	56.92	52.23	51.13	50.42	50.20	49.45	2.12	2.05	1.95	1.86
T_8	65.00	54.39	51.57	45.88	51.00	50.10	49.77	48.90	2.09	1.78	1.67	1.57
T_9	63.88	53.92	51.96	48.83	50.84	48.42	47.90	47.44	2.10	1.63	1.57	1.50
T_{10}	59.67	50.14	46.87	42.60	50.84	48.00	47.49	46.87	2.05	1.37	1.30	1.20
T_{11}	63.88	54.14	52.10	49.13	52.00	48.55	48.06	47.56	2.14	1.64	1.59	1.51
T_{12}	62.00	50.33	47.00	42.86	50.68	48.15	47.61	47.00	2.12	1.40	1.32	1.23
T_{13}	57.00	56.57	54.56	51.53	53.66	49.25	48.77	48.53	2.05	1.83	1.78	1.70
T_{14}	60.67	52.47	49.27	45.12	53.66	48.88	48.40	47.90	2.10	1.55	1.47	1.38
T_{15}	62.00	56.74	54.73	51.72	50.84	49.34	48.90	48.60	2.02	1.84	1.79	1.72
T_{16}	60.67	52.67	49.46	45.49	50.84	49.00	48.53	48.10	2.09	1.57	1.49	1.39
T_{17}	61.34	52.49	49.86	46.52	51.81	48.45	47.92	47.40	2.10	1.54	1.48	0.95
Mean	62.22	54.80	52.27	48.46	51.31	49.35	48.95	48.82	2.09	1.72	1.66	1.54
CD at 5%	1.80	2.37	2.32	2.80	0.47	0.63	0.41	0.99	NS	0.23	0.21	0.24

Ascorbic acid

From the analysis of the data shown in Table 1 and 2, it was observed that the post-harvest treatments and PPP packaging at different perforation had a significant influence in vitamin C content of fruits. A significant difference and gradual decline in Vit-C were observed across the storage period from 0 days to 6 days after harvest ranging between 62.22±5.57 and 48.46±13.88 mg/100 g pulp. But a notable variation in vitamin-C content of fruit under different treatments was observed as storage duration progressed (p=1.82398E-10). It was observed that fruits treated with calcium chloride @ 1% and 2%, wax emulsion @ 5% and 10% and Kaolin @ 1% and 2% packed in PPP @ 6% perforation showed a consistency to maintain the vitamin-C content at end of storage (51.53 to 54.48 mg/100g pulp) compared to other given treatments including control (42.60 to 49.13mg/100g pulp). On further examination it was noted that the fruit packed in PPP @ 6% perforation had higher vitamin C content over PPP @ 9% perforation. The ascorbic content decreased gradually with the advancement of storage period. During storage, oxidizing enzymes like ascorbic acid oxidase, peroxidase, catalase and polyphenol oxidase might be causing a decrease in the ascorbic content of the fruits (Singh et al., 2005; Piga et al., 2003). Similarly, Kaushik et al. (2014) observed a significant decline in ascorbic acid in minimally processed Bombai litchi stored at 5 ^{0}C for 12 days. Shah and Nath (2008) also found the same decreasing trend in Rose scented variety of litchi fruits with anti-browning agent and vacuum packaged during storage at 4±2 ^{0}C for 24 days. The decrease in ascorbic using calcium nitrate has also been reported by Mahajan et al. (2005); Ray et al. (2005) in litchi fruits. Jadhao et al. (2008) observed that kagzi lime stored in 200 gauge perforated polypropylene bags under cold storage recorded maximum ascorbic acid.

Anthocyanin content of peel

The results depicted in Table 2 and 3 showed that effect of chemicals and storage of fruits under polypropylene plastic (PPP) at different level of perforation showed a significant effect on anthocyanin content of the peel. A notable variation in anthocyanin content of the peel was registered as storage duration progressed (p=3.66E-07). A significant variation and gradual decline from initial (0 DAH) to end of storage (6 DAH) in anthocyanin content of the peel was observed in chemically treated fruits with PPP packaging ranging between 51.31±0.99 (0 DAH) and 48.42±0.84 (6 DAH) mg/100g peel. It was notified that the performance of calcium chloride @ 1% and 2% and wax emulsion @ 5% and 10% packed in PPP @ 6% and 9% perforation were statistically at par and observed more anthocyanin content in peel (48.90 to 49.67 mg/100g peel) at end of storage (6 DAH) compared to other given treatments including control (47.40 mg/100g peel). The discolouration of fruits followed by degradation of anthocyanin in progress of storage period was also confirmed by Neog and Saikia (2010). Retention of anthocyanin content was better in 1% calcium chloride at low temperature. The discolouration of anthocyanin with increase in storage period may be due to enzymatic activity (PPO and peroxidase) which resulted in the hydrolysis of anthocyanins into sugar and others (Jiang et al., 2003; Ducamp et al., 2007). Consistent with the study, Singh et al. (2008) reported retention of anthocyanin till 6 days of storage in strawberry fruits treated with 2% calcium nitrate and packed in HDPE crates. Litchi cv. Mauritius fruits stored in MAP (BOPP-3, 35µm size, 0.00939% perforations) under 95% R. H. at 2 ºC temperature for 34 days retained colour (Sivakumar and Korsten, 2006b).

Table 3. Performance of initial (0 DAH) and final storage (6 DAH) influenced by chemicals and MAP in different variables

Variables	Mean ± SD		Difference between 0 DAH to 6 DAH	Calculated t value	t-critical (two tailed)	*P value*
	0 DAH	6 DAH				
TSS (°B)	14.79±0.03	16.82±0.17	2.03	-21.08	2.12	4.23129E-13<0.05
Total sugar (%)	8.90±0.02	10.63±0.19	1.73	-14.83	2.12	9.08E-11<0.05
Titratable acidity (%)	0.69±0.001	0.60±0.004	0.09	4.81	2.12	0.0001914<0.05
Ascorbic acid (mg/100g pulp)	62.22±5.57	48.46±13.88	13.76	14.15	2.12	1.82398E-10<0.05
Anthocyanin (mg/100g peel)	51.31±0.99	48.42±0.84	2.89	8.26	2.12	3.66E-07<0.05
Firmness (kg cm^{-2})	2.09±0.001	1.54±0.067	0.55	8.50	2.12	2.49873E-07<0.05

Firmness

The results depicted in Table 1 and 2 showed that effect of chemicals and storage of fruits under polypropylene plastic (PPP) at different level of perforation had no significant effect on textural profile of fruit initially. But a notable variation in fruit firmness was observed as storage duration progressed (p=2.49873E-07). A significant difference (0.55 kg cm^{-2}) and gradual decline from initial (0 DAH) to end of storage (6 DAH) in aril firmness of fruit was observed across chemically treated fruits and PPP packaging ranging between 2.09±0.001 and 1.54±0.067 kg cm^{-2}. It was observed that fruits treated with calcium chloride @ 1% and 2% and wax emulsion @ 5% and 10% packed in PPP @ 6% perforation were statistically at par and observed firmer fruits (1.85 to 1.90 kg cm^{-2}) compared to other treatments given including control (0.95 to 1.72kg cm^{-2}) from 2 DAH to end of storage (6 DAH). Consistent with the study, Mphahlele et al. (2020) observed a significant decline in fruit firmness cv. Mauritius ranging between 14.4 N and 16.0 N across all package type (0 perforation, 1.1 mm perforation, 5.4 perforation).

Similarly, Phanumong et al. (2015) noted a decline in firmness for non-treated fruit cvs. Hongyuay, Gimseng and Jugkapat packed in polystyrene clamshell and stored at 4±1^{0}C for 12 days. Loss of firmness/softening in fruits is generally associated with degradation of cell wall by hydrolytic enzymes such as polygalacturonase and pectin methyl esterase (Hobson, 1963; Tanada-Palmu and Grosso, 2005). Reason for maintaining fruit firmness by calcium was due to thickening of middle lamella of the fruit cells owing to increased formation of deposition of calcium pectate (Gupta et al., 1984). The combination of calcium chloride 1% and MAP has retained the firmness of minimally processed Golden Delicious apples (Soliva-Fortuny et al., 2003) and in fresh-cut papaya (Waghmare and Annapure, 2013).

CONCLUSION

Freshness and colour of litchi fruits deteriorates very fast right after harvest. So, dipping fruits right after pre cooling in calcium chloride (1% and 2%) solution packed in polypropylene plastic @ 6% perforation improved the biochemical composition of fruits like ascorbic acid, fruit firmness with higher anthocyanin retention and decline in acidity.

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