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STUDIES OF VARIOUS ORGANIC ACID TREATMENTS FOR IMPROVING SHELF LIFE OF LITCHI (*LITCHI CHINENSIS* SONN.) cv. DEHRADUN UNDER COLD STORAGE CONDITION

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Abstract

The post-harvest experiment was conducted during summer season of 2017- 18. The experiment was laid out in a Completely Randomized Design (CRD) with three replications. There were eight treatments used including control and remaining treatments were Chitosan (1%), Ascorbic Acid (5%), Ascorbic Acid (10%), Citric Acid (5%), Citric Acid (10%), Oxalic Acid (5%), Oxalic Acid (10%). The Fruits were dipped in different solution of these chemicals. The physical and chemical parameters data viz. fruit length, weight, width, volume, TSS, Acidity, Ascorbic acid, Reducing sugar, Non reducing sugar, total sugar were recorded under cold storage conditions at 1st, 3rd, 5th, 7th, 9th, 11th, 13th, 15th days after post harvest treatment. Post harvest storage studies revealed that under cold storage conditions, fruits treated with chitosan 1% treatment showed slower rate of reduction in fruit size, weight and fruit volume and these parameters was significantly affected by other treatments. There were significant effects of treatments on chemical parameters like TSS, ascorbic acid, total sugar. The highest TSS was recorded from the fruits treated with oxalic acid 5%. The maximum total sugar was recorded in Oxalic acid 10% treatment. The Chitosan 1% treatment will serve as a good alternative for prolonging shelf life and reducing browning of litchi fruits.

Key words : Litchi, shelf life, chitosan, ascorbic acid, citric acid , oxalic acid, post harvest.

Introduction

The litchi (*Litchi chinensis* Sonn.) is a very significant subtropic fruit crop belongs to family Sapindaceae. It's extremely specific in climatical requirements and possibly because of this cause its farming is limited to few countries within the globe. Worldwide, commercial litchi production is centered largely in the Northern hemisphere, with growing areas including China, Thailand, Taiwan, India, USA and Israel (Menzel, 2001). Production wise India ranked second, next to China for litchi, with an yearly production of 483.30 thousand metric tonnes from an area of 74.40 thousand hectares with productivity of 6.50 metric tons ha^{-1}.In Punjab, commercial cultivation of litchi is restricted in the northern part (Gurdaspur, Pathankot), particularly in the foothills of Himalayas from Tripura to Jammu & Kashmir and Gangetic plains. Litchi comprises 1.6% and 1.0% of the total area and production under fruit crops . Skin browning due to moisture loss is a major limitation in the retention of colour in litchi, fruit deteriorating rapidly after harvest, often within 2 to 3 days (Huang and Scott, 1985). Litchi is very delicate in nature and highly perishable, which accounts for its low shelf life. Wherever, it is grown, its shelf life under ambient conditions is never more than 24-72 hours (Kumar, 2000). Cold storage at 1–5°C is used to minimize rotten decay to diseases, but has only limited function in minimizing pericarp browning. Moreover, the fruits deteriorate rapidly when removed from cold storage. Long-term storage of litchi at less temperature (separately water loss and browning) is also linked with loss of flavour and therefore, poor eating quality (Jiang and Li, 2003). Coating methods were also conducted to enhancing litchi fruits appropriateness to storage (Ghosh *et al*., 1998). Cationic polysaccharide,

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Chitosan was utilized to reduce browning of litchi fruits pericarp (Zhang and Quantick, 1997). Recently, ascorbic acid is found for effective to manage browning due to enzymes in fruits and vegetables (Santerre *et al*., 1988; Sapers *et al*., 1989).

Materials and Methods

The experiment was conducted in the Post Graduate Laboratory, Department of Horticulture, School of Agriculture, Lovely Professional University, Phagwara, India. The present investigation was carried out soon after harvesting of litchi on 8th June 2017. The experimental material consisted of freshly harvested, mature litchi fruits of cultivar Dehradun. The litchi fruits were collected in the bunches, which were harvested from the orchard of Agriculture Department in Gurdaspur. Fruits were kept in muslin cloth bags, covered with a thick layer of green litchi leaves and brought to the laboratory. Jerks during transit were avoided. Fruits were selected according to uniform size and colour, blemished and diseased fruit were discarded. Prior to the application of post-harvest treatments, destalking of the fruits with the help of sharp scissor was done by retaining only 2mm pedicels in each fruit. Pre-cooling was also done before the experiment. The pre-cooled fruits were air dried prior to the application of treatments. The treated and non-treated fruits were divided into different lots and placed in a perforated brown bag. The experiment was carried out under cold storage condition (2°C).

Results and Discussion

The present research has been carried out in different cold storage condition. Results obtained from present investigation are briefly enumerated as follow:

Fruit length and width under cold storage conditions

The range of fruit length varied from 3.13 to 3.33cm. The maximum fruit length 3.33cm was recorded for T7 (Oxalic Acid 10%) followed by T6 (Oxalic Acid 5%) *i.e.* 3.26cm. The minimum fruit length 3.16cm was recorded in T1 (Chitosan 1%) treatment. As compared to T1, T7 showed 6.39% increase in fruit length. The range of fruit width varied from 2.86 to 3.21cm. The maximum value for fruit width was 3.21cm recorded for T3 (Ascorbic Acid 10%) followed by T7 (Oxalic Acid 10%) *i.e.* 3.19cm. The minimum value for fruit width was 2.86cm recorded for T0 (Control 1%). As compared to T7, T0 showed 12.24% increase in fruit width. The results showed that there was significant effect of organic acid treatments on the size of fruit. Fruit length and width were found decreasing during storage period under cold storage conditions. At the harvest day, all treatments showed maximum fruit size. It might be due to less moisture loss. More loss in moisture affects shrinkage and loss of turgidity of the fruits during the storage. However, the lesser decrease of fruit length and width was observed in T1 (Chitosan 1%) treated fruits which may be due to retarded process of respiration and transpiration or less rate of the moisture loss from the fruits. The result is conformity with finding of Rattanapanone *et al.* (2007) as he reported that the post harvest edible coating treatments had significant effect on fruit length and width of litchi fruits.

Fruit weight and volume under cold storage conditions

The range of fruit weight varied from 16.48 to 20.90g. The maximum value for fruit weight was 20.90g recorded for T3 (Ascorbic Acid 10%) followed by T6 (Oxalic Acid 5%) *i.e.* 20.63g. The minimum value for fruit weight was 16.48g recorded for T1 (Chitosan 1%). As compared to T1, T3 showed 26.82% increase in fruit weight. The range of fruit volume varied from 19.60 to 23.74cc. The maximum value for fruit volume was 23.74cc recorded for T1 (Chitosan 1%) followed by T2 (Ascorbic Acid

Table 1 : Effect of organic acids on fruit length (cm) under cold storage conditions.

Treatment	Fruit length (cm)								
	Day 1	Day 3	Day 5	Day 7	Day 9	Day 11	Day 13	Day 15	Mean
T_0	$3.31^{a}\pm0.05$	$3.19^{bc}\pm0.01$	$3.15^{b}\pm0.01$	$3.16^{a}\pm0.006$	$3.11^{abc}\pm0.01$	$3.11^{abc}\pm0.03$	$3.09^{a}\pm0.03$	$3.07^{ab}\pm0.04$	3.16
T_1	$3.26^{a}\pm0.09$	$3.16^{c}\pm0.09$	$3.12^{b}\pm0.05$	$3.28^{a}\pm0.13$	$3.03^{c}\pm0.04$	$3.03^{c}\pm0.006$	$3.00^{a}\pm0.01$	$2.94^{ab}\pm0.03$	3.13
T_2	$3.29^{a}\pm0.03$	$3.35^{ab}\pm0.10$	$3.21^{ab}\pm0.03$	$3.33^{a}\pm0.03$	$3.15^{abc}\pm0.07$	$3.15^{abc}\pm0.07$	$3.22^{a}\pm9.94$	$3.02^{ab}\pm0.05$	3.21
T_3	$3.47^{a}\pm0.06$	$3.39^{a}\pm0.05$	$3.34^{a}\pm0.04$	$3.37^{a}\pm0.05$	$3.29^{ab}\pm0.04$	$3.29^{ab}\pm0.04$	$3.22^{a}\pm0.02$	$3.13^{ab}\pm0.03$	3.33
T_4	$3.38^{a}\pm0.06$	$3.33^{abc}\pm0.01$	$3.30^{ab}\pm0.03$	$3.32^{a}\pm0.03$	$3.15^{abc}\pm0.04$	$3.15^{abc}\pm0.08$	$3.14^{a}\pm0.09$	$2.76^{b}\pm0.27$	3.22
T_5	$3.28^{a}\pm0.07$	$3.19^{bc}\pm0.08$	$3.14^{b}\pm0.06$	$3.16^{a}\pm0.06$	$3.10^{bc}\pm0.06$	$3.10^{bc}\pm0.08$	$3.08^{a}\pm0.08$	$3.03^{ab}\pm0.83$	3.16
T_6	$3.42^{a}\pm0.38$	$3.30^{abc}\pm0.04$	$3.25^{ab}\pm0.01$	$3.29^{a}\pm0.005$	$3.29^{ab}\pm0.01$	$3.29^{ab}\pm0.04$	$3.18^{a}\pm0.04$	$3.09^{ab}\pm0.06$	3.26
T_7	$3.44^{a}\pm0.02$	$3.37^{a}\pm0.05$	$3.29^{ab}\pm0.10$	$3.38^{a}\pm0.10$	$3.32^{a}\pm0.08$	$3.32^{a}\pm0.09$	$3.31^{a}\pm0.081$	$3.22^{a}\pm0.07$	3.34

Note : T0 (Control), T1 (Chitosan 1%), T2 (Ascorbic Acid 5%), T3 (Ascorbic Acid 10%), T4 (Citric Acid 5%), T5 (Citric Acid 10%), T6 (Oxalic Acid 5%), T7(Oxalic Acid 10%.

5%) *i.e.* 21.25cc. The minimum value recorded for fruit volume was 19.60 cc recorded for T7 (Oxalic Acid 10%). As compared to T7, T1 showed 21.12% increase in fruit volume. The weight and volume of fruits decreased consistently with the increase in storage periods under ambient as well as cold storage. However, the rate of decrease was slower in T1 (Chitosan 1%) treated fruits. The chitosan treated fruits, resulted in minimum volume and weight and volume loss during storage. Lesser rate of reduction in volume and weight loss of the fruits in treatment of chitosan may be due to retarded process of respiration and transpiration or rate of the moisture loss from the fruits (Jiang *et al*., 2007).

TSS under cold storage conditions

The range of TSS varied from 18.27 to 20.60Brix^0. The maximum value for TSS was 20.60Brix^0 recoded for T6 (Oxalic Acid 5%) followed by T5 (Citric Acid 10%) *i.e.* 20.57Brix^0. The minimum value for TSS was 18.27Brix^0 recorded for T0 (Control). As compared to T0, T6 showed 12.75% increase in TSS. It is obvious that the TSS content of fruits increase with increase in duration of storage, reaches its peak, and then decline gradually thereafter. However in Trial I, it was observed that TSS level of fruits starts increasing right from the first day which proceed up to the end of the 6 days storage period. Continuous increase in TSS up to 5 days of storage at ambient conditions has also been reported by Upreti (1988) in litchi cv. Rose Scented. The TSS of the fruits were found increasing up to 14 days of storage.

In present investigation, superior TSS level was noted in T6 (Oxalic acid 5%) treatment, while the least effect was recorded in T1 (chitosan 1%) treatment. Increase in TSS of fruit during storage at ambient and low temperature storage conditions might be due to considerable loss of water from fruits (Paul and Chen, 1987; Kumar, 1994; Mahajan *et al*., 2003 and Ray *et al*., 2004) in which the concentration of sugars might have increased. Ray *et al*. (2004) observed that TSS content in litchi aril increased during the initial stage of storage which then decreased slowly irrespective of all treatments till the last day of observation and TSS increased upto 13th day of storage. The maintenance of TSS in stored fruits may be due to the decline in hydrolytic enzymes that are associated with fruit ripening (Balakrishnan, 1998).

Titratable acidity under cold storage conditions

The range of titratable acidity varied from 0.39 to 0.55%. The maximum value for titratable acidity was 0.55% recorded for T7 (Oxalic Acid 10%) followed by T1 (Chitosan 1%) *i.e.* 0.52%. The minimum value for

Table 2 : Effect of organic acids on fruit volume (cc) under cold storage conditions.

Treatment	Volume (cc)							
	Day 1	Day 3	Day 5	Day 7	Day 9	Day 11	Day 13	Day 15	Mean
T_0	22.45^{b}±0.026	22.27^{b}±0.039	20.64^{cd}±0.693	20.46^{b}±0.688	19.97^{cd}±0.537	19.94^{b}±0.689	19.53^{cd}±0.635	19.38^{cde}±0.633	20.58
T_1	23.69^{a}±0.020	23.59^{a}±0.014	23.48^{a} ±0.020	23.36^{a}±0.027	23.06^{a} ±0.034	25.99^{a}±2.330	23.45^{a} ±0.026	23.32^{a}±0.023	23.74
T_2	22.81^{b}±0.023	22.68^{b}±0.025	22.49^{b}±0.022	14.91^{a}±7.458	22.08^{b}±0.031	21.90^{b}±0.011	21.71^{b}±0.035	21.46^{b}±0.024	21.25
T_3	20.25^{d}±0.033	20.12^{d}±0.055	19.95^{d}±0.046	19.79^{a}±0.049	19.46^{d} ±0.048	19.26^{b}±0.034	19.00^{d}±0.017	18.78^{d}±0.030	19.57
T_4	20.61^{d}±0.058	20.45^{d}±0.058	20.25^{cd}±0.041	20.15^{a}±0.052	19.38^{d}±0.218	19.30^{b}±0.201	19.04^{d}±0.184	18.85^{de}±0.183	19.75
T_5	20.30^{d}±0.355	20.15^{d}±0.335	19.93^{d}±0.336	19.74^{a}±0.318	19.39^{d}±0.317	19.82^{b}±0.026	19.75^{cd}±0.028	19.66^{cd}±0.035	19.84
T_6	21.26^{c}±0.233	21.11^{c}±0.231	20.93^{c} ±0.245	20.79^{a}±0.220	20.61^{c}±0.222	20.38^{b}±0.193	20.06^{c} ±0.166	19.76^{c}±0.298	20.61
T_7	20.18^{d}±0.026	20.03^{d}±0.040	19.86^{d}±0.041	19.68^{a}±0.045	19.55^{d}±0.038	19.38^{b}±0.078	19.20^{d}±0.059	18.93^{de}±0.030	19.60

Note : T0 (Control), T1 (Chitosan 1%), T2 (Ascorbic Acid 5%), T3 (Ascorbic Acid 10%), T4 (Citric Acid 5%), T5 (Citric Acid 10%), T6 (Oxalic Acid 5%), T7(Oxalic Acid 10%.

Table 3 : Effect of organic acids on TSS (Brix^0) under cold storage conditions

Treatment	TSS (°Brix)								
	Day 1	Day 3	Day 5	Day 7	Day 9	Day 11	Day 13	Day 15	Mean
T_0	15.72^{b}±0.02	15.9^{e}±0.01	16.04^{d}±0.09	19.26^{e}±0.01	19.45^{d}±0.01	19.71^{cd}±0.01	19.95^{c}±0.01	20.18^{e}±0.02	18.27
T_1	18.6^{e}±0.07	18.73^{d}±0.01	18.86^{b}±0.01	19.02^{c}±0.01	19.15^{c}±0.01	19.36^{b}±0.01	19.35^{b}±0.08	19.63^{d}±0.02	19.08
T_2	18.5^{d}±0.01	18.65^{bc}±0.03	19.8^{c}±0.01	19.95^{d}±0.02	20.15^{d}±0.01	20.28^{b}±0.01	20.5^{ab}±0.12	20.65^{cd}±0.02	19.81
T_3	19.55^{c}±0.01	19.72^{b}±0.01	19.90^{c}±0.01	20.07^{cd}±0.01	20.26^{bc}±0.01	20.50^{b}±0.01	20.56^{c}±0.04	20.91^{c}±0.01	20.18
T_4	19.8^{bc}±0.01	19.95^{ab}±0.04	20.05^{ab}±0.01	20.27^{c}±0.01	20.34^{b}±0.00	20.55^{bc}±0.01	20.83^{bc}±0.03	20.71^{bc}±0.36	20.43
T_5	19.88^{c}±0.10	19.98^{b}±0.00	20.3^{b}±0.01	20.5^{b}±0.01	20.7^{ab}±0.01	20.85^{c}±0.01	21.10^{a}±0.03	21.30^{a}±0.03	20.57
T_6	20.08^{a}±0.04	20.18^{ab}±0.04	20.31^{a}±0.01	20.3^{ab}±0.01	20.51^{b}±0.04	21.13^{a}±0.01	21.14^{ab}±0.03	21.18^{bc}±0.03	20.60
T_7	18.75^{b}±0.01	18.90^{a}±0.05	19.06^{b}±0.01	19.35^{a}±0.01	19.45^{a}±0.01	19.71^{a}±0.02	19.93^{a}±0.04	20.18^{b}±0.01	19.46

Note : T0 (Control), T1 (Chitosan 1%), T2 (Ascorbic Acid 5%), T3 (Ascorbic Acid 10%), T4 (Citric Acid 5%), T5 (Citric Acid 10%), T6 (Oxalic Acid 5%), T7(Oxalic Acid 10%).

Table 4 : Effect of organic acids on titratable acidity (%) under cold storage conditions.

Treatment	Titratable Acidity (%)								
	Day 1	Day 3	Day 5	Day 7	Day 9	Day 11	Day 13	Day 15	Mean
T_0	0.48^{e}±0.003	0.46^{e} ±0.008	0.43^{f}±0.003	0.41^{f}±0.003	0.40^{e} ±0.003	0.38^{f}±0.003	0.35^{d}±0.005	0.26^{e}±0.003	0.39
T_1	0.64^{b}±0.005	0.61^{b}±0.005	0.59^{c}±0.005	0.55^{c}±0.005	0.51^{b}±0.003	0.48^{b}±0.003	0.41^{a}±0.006	0.35^{a}±0.003	0.52
T_2	0.52^{d}±0.006	0.49^{e}±0.006	0.49^{e}±0.005	0.47^{e}±0.003	0.45^{d}±0.003	0.43^{e}±0.005	0.36^{cd}±0.005	0.28^{d}±0.005	0.43
T_3	0.56^{c}±0.006	0.53^{d}±0.005	0.51^{d}±0.003	0.47^{e}±0.008	0.46^{cd}±0.003	0.44^{de}±0.003	0.37^{bc}±0.003	0.29^{d}±0.003	0.45
T_4	0.57^{c}±0.005	0.54^{cd}±0.003	0.50^{e}±0.005	0.48^{e}±0.003	0.46^{cd}±0.008	0.45^{cde}±0.01	0.41^{a} ±0.005	0.33^{b}±0.005	0.47
T_5	0.58^{c}±0.008	0.55^{c}±0.003	0.52^{d}±0.003	0.50^{d}±0.005	0.47^{c}±0.006	0.46^{cd}±0.005	0.40^{a}±0.003	0.31^{bc}±0.003	0.48
T_6	0.64^{b}±0.006	0.62^{ab}±0.005	0.61^{b}±0.003	0.56^{b}±0.003	0.51^{b}±0.003	0.47^{bc}±0.005	0.38^{b}±0.003	0.28^{d}±0.006	0.51
T_7	0.67^{a}±0.006	0.63^{a}±0.008	0.62^{a}±0.003	0.60^{a}±0.003	0.58^{a} ±0.003	0.55^{a}±0.009	0.42^{a}±0.008	0.31^{c}±0.005	0.55

Note : T0 (Control), T1 (Chitosan 1%), T2 (Ascorbic Acid 5%), T3 (Ascorbic Acid 10%), T4 (Citric Acid 5%), T5 (Citric Acid 10%), T6 (Oxalic Acid 5%), T7(Oxalic Acid 10%).

titratable acidity was 0.39% recorded for T0 (Control). As compared to T0, T7 showed 41.03% increase in titratable acidity. Results revealed that T8 (Oxalic acid 10%) treatment show maximum decline in acidity during storage of 6 days This may be because of accumulation of sugars in fruits (Misra and Khan, 1981) or because of converting acids into salts and sugar by the enzymes, significantly invertase (Kumar *et al*., 1992) or because of utilization of organic acids in respiratory metastasis} process and alternative biodegradable reactions (Mahajan, 1997). The experiment II conducted under cold conditions, T1 (Chitosan 1%) treatment showed most decline in acidity throughout storage amount of fourteen days. Chitosan coating treatment with raised rate of declining in concentration of titratable acidity within the fruits. Du *et al*. (1997) found that use of coating with chitosan suppressed respiration pace of Japanese pear, peach and kiwifruit. Less respiration pace was found of litchi fruit treated with chitosan following twenty days of storage at 2°C. Thus, the less levels of titratable acidity within the litchi fruit pulp coated with chitosan could also be because of protecting Oxygen obstacle or lessening of oxygen supply on the fruit surface that suppressed respiratory process (Jiang and Li, 2000 and Yonemoto *et al*., 2002). Sivakumar *et al*. (2005); Sivakumar and Korsten (2006) and Semeer Babu *et al*. (2007) found change at significant level in titratable acidity of fruits under low temperature storage conditions. A gradual declining trend in the acidity content of fruit in all the treatments was observed with the progression of storage period in spite of of post harvest treatments. Alike observation were observed by Gaur and Bajpai (1978), Chandel (1987) and Rawat (2001). The decrease in acidity might be due to the general catabolisation of organic acids and its converting to sugars (Pantastico, 1975). Paul and Chen (1987) reported a decline in titratable acidity in storage condition irrespective of storing temperatures.

Ascorbic acid under cold storage conditions

The range of ascorbic acid content varied from 25.31 to 27.42mg/100g. The maximum value for ascorbic acid

Table 5 : Effect of organic acids on ascorbic acid (mg/100g) under cold storage conditions.

Treatment	Ascorbic acid (mg/100g)								
	Day 1	Day 3	Day 5	Day 7	Day 9	Day 11	Day 13	Day 15	Mean
T_0	31.63^{e}±0.012	29.70^{f}±0.012	27.54^{e}±0.005	25.32^{e}±0.006	23.94^{f}±0.015	23.17^{c}±0.020	21.47^{e}±0.321	19.75^{f} ±0.021	25.31
T_1	32.78^{b}±0.008	31.24^{b}±0.005	29.97^{b}±0.006	26.68^{c}±0.005	26.06^{a}±0.005	24.23^{b}±0.031	23.67^{a}±0.020	22.14^{a}±0.026	27.12
T_2	33.52^{c}±0.005	31.78^{b}±0.006	30.70^{bc}±0.008	27.05^{b}±0.028	24.48^{cd}±0.006	22.73^{d}±0.026	20.72^{f}±0.014	19.72^{f}±0.017	26.33
T_3	32.10^{b}±0.006	30.60^{e}±0.006	29.21^{d}±0.006	27.16^{b}±0.011	25.67^{c}±0.007	24.16^{b}±0.318	23.35^{b}±0.016	21.67^{b}±0.009	26.74
T_4	34.10^{a}±0.005	31.93^{a}±0.008	30.75^{a}±0.008	27.66^{a}±0.005	25.87^{b}±0.005	24.62^{a}±0.021	23.02^{c}±0.020	21.55^{c}±0.020	27.45
T_5	31.71^{d}±0.006	30.17^{e}±0.005	28.80^{d}±0.003	26.38^{d}±0.006	25.11^{c}±0.008	23.43^{c}±0.023	22.25^{d}±0.032	20.34^{d}±0.017	26.02
T_6	32.60^{b}±0.008	30.25^{d}±0.006	28.47^{e}±0.006	25.57^{d}±0.008	24.10^{e}±0.007	23.15^{c}±0.023	21.65^{d}±0.020	20.72^{cd}±0.015	25.81
T_7	33.64^{a}±0.006	31.20^{e}±0.005	29.97^{b}±0.005	26.70^{e}±0.006	25.89^{b}±0.005	23.88^{b}±0.029	21.88^{c}±0.026	20.91^{b}±0.016	26.72

Note : T0 (Control), T1 (Chitosan 1%), T2 (Ascorbic Acid 5%), T3 (Ascorbic Acid 10%), T4 (Citric Acid 5%), T5 (Citric Acid 10%), T6 (Oxalic Acid 5%), T7(Oxalic Acid 10%).

Table 6: Effect of organic acids on reducing sugar (%) under cold storage conditions

Treatment	Reducing sugar (%)								
	Day 1	Day 3	Day 5	Day 7	Day 9	Day 11	Day 13	Day 15	Mean
T_0	9.55^{e}±0.005	9.63^{e}±0.035	9.63^{f}±0.008	9.66^{e}±0.014	9.68^{e}±0.020	9.70^{e}±0.036	9.76^{e}±0.023	9.80^{e} ±0.021	9.67
T_1	10.06^{b}±0.008	10.12^{ab}±0.017	10.15^{b}±0.017	10.20^{ab}±0.024	10.23^{ab}±0.026	10.26^{ab}±0.026	10.29^{ab}±0.026	10.32^{ab}±0.023	10.20
T_2	9.70^{d}±0.012	9.74^{d}±0.014	9.77^{e}±0.018	9.81^{d}±0.018	9.84^{d}±0.021	9.87^{d}±0.024	9.91^{d}±0.020	9.94^{d}±0.026	9.82
T_3	9.76^{c}±0.005	9.80^{e}±0.005	9.83^{d}±0.005	9.86^{cd}±0.008	9.90^{d}±0.009	9.94^{cd}±0.012	9.98^{de}±0.017	10.03^{cd}±0.017	9.89
T_4	9.86^{c}±0.005	9.89^{b}±0.008	9.92^{c}±0.012	9.96^{c}±0.015	10.00^{cd}±0.020	10.04^{d}±0.024	10.08^{d}±0.021	10.11^{c}±0.026	9.98
T_5	10.04^{b}±0.020	10.06^{cd}±0.003	10.10^{b}±0.008	10.12^{b}±0.008	10.14^{c}±0.012	10.17^{c}±0.012	10.21^{c}±0.020	10.23^{b}±0.024	10.13
T_6	10.06^{b}±0.005	10.11^{ab}±0.006	10.13^{bc}±0.008	10.16^{ab}±0.008	10.19^{ab}±0.008	10.23^{ab}±0.012	10.26^{bc}±0.014	10.29^{bc}±0.018	10.18
T_7	10.11^{a}±0.003	10.17^{a}±0.004	10.21^{a}±0.006	10.24^{a}±0.011	10.27^{a}±0.011	10.31^{a}±0.012	10.34^{a}±0.008	10.38^{a}±0.012	10.25

Note : T0 (Control), T1 (Chitosan 1%), T2 (Ascorbic Acid 5%), T3 (Ascorbic Acid 10%), T4 (Citric Acid 5%), T5 (Citric Acid 10%), T6 (Oxalic Acid 5%), T7(Oxalic Acid 10%).

Table 7: Effect of organic acids on non-reducing sugar (%) under cold conditions

Treatment	Non Reducing Sugar (%)								
	Day 1	Day 3	Day 5	Day 7	Day 9	Day 11	Day 13	Day 15	Mean
T_0	1.98^{f} ±0.011	1.95^{a}±0.012	1.94^{e} ±0.012	1.93^{f} ±0.011	1.90^{e}±0.014	1.94^{f}±0.012	1.92^{e}±0.010	1.95^{e}±0.020	1.94
T_1	2.24^{c} ±0.008	2.21^{a}±0.005	2.22^{c}±0.028	2.19^{d} ±0.006	2.20^{cd}±0.005	2.21^{d}±0.006	2.19^{c}±0.008	2.19^{c}±0.005	2.21
T_2	2.14^{de}±0.006	2.14^{a}±0.003	2.16^{d}±0.005	2.15^{e} ±0.003	2.15^{d}±0.005	2.14^{de}±0.003	2.15^{d}±0.005	2.13^{c}±0.014	2.14
T_3	2.13^{e} ±0.011	2.10^{a}±0.002	2.10^{d}±0.003	2.09^{e} ±0.003	2.08^{d}±0.003	2.06^{e}±0.003	2.04^{e}±0.003	2.04^{d}±0.005	2.08
T_4	2.16^{d}±0.008	2.17^{a}±0.003	2.17^{c}±0.008	2.16^{d} ±0.008	2.17^{c}±0.006	2.16^{d}±0.006	2.15^{d}±0.005	2.14^{bc}±0.006	2.16
T_5	2.22^{c}±0.005	1.47^{a}±0.735	2.21^{bc}±0.003	2.23^{c} ±0.003	2.24^{c}±0.003	2.24^{c}±0.003	2.22^{c}±0.003	2.22^{c}±0.005	2.13
T_6	2.27^{b}±0.008	2.26^{a}±0.006	2.26^{b}±0.003	2.28^{b} ±0.002	2.29^{b}±0.008	2.30^{b}±0.012	2.29^{b}±0.008	2.28^{bc}±0.008	2.28
T_7	2.32^{a}±0.012	1.54^{a}±0.773	2.32^{a}±0.005	2.21^{a} ±0.002	2.33^{a}±0.005	2.33^{a}±0.008	2.31^{a}±0.008	2.35^{a}±0.010	2.23

Note : T0 (Control), T1 (Chitosan 1%), T2 (Ascorbic Acid 5%), T3 (Ascorbic Acid 10%), T4 (Citric Acid 5%), T5 (Citric Acid 10%), T6 (Oxalic Acid 5%), T7(Oxalic Acid 10%).

was 27.42mg/100g recorded for T4 (Citric Acid 5%) followed by T1 (Chitosan 1%) *i.e.* 27.12mg/100g. The minimum value for ascorbic acid was recorded 25.31mg/100g for T0 (Control). As compared to T4 showed 8.34% increase in ascorbic acid. Present investigations reveal reduction in ascorbic acid throughout the storage period regardless of storage temperatures and treatments in cold storage conditions. The highest ascorbic acid content was reported in the initial days of storage. Paul and Chen (1987) reported a major decline in ascorbic acid in which 50 percent reduction occurred within 4 days, irrespective of the storage method and temperature. Enormous loss in ascorbic acid has also been reported by Gaur and Bajpai (1978). Decline in ascorbic acid content from 29.59 to 5.32 mg/100g pulp during 18 days of low temperature storage may be because of the fact that ascorbic acid being sensitive to oxygen heat and light, was oxidized easily in the occurrence of oxygen by both non-enzymatic and non enzymatic catalyst, and therefore, is more likely to be lost during storage as reported earlier by Mapson (1970) and Rai *et al*. (2002).

Reducing sugar under cold storage conditions

The range of reducing sugar varied from 9.67 to 10.25%. The maximum value for reducing sugar was 10.25% recorded for T7 (Oxalic Acid 10%) followed by T1 (Chitosan 1%) *i.e.* 10.20%. The minimum value for reducing sugar was 9.67% recorded for T0 (Control). As compared to T0, T7 showed 6% increase in reducing sugar. The present studies revealed that initially reducing sugar content of litchi rises and continued till last day of storage. The highest increase in reducing sugar under ambient conditions was obtained in T5 (Citric Acid 10%) and in Trail under cold condition the highest increase in reducing sugar was obtained in T7 (Oxalic Acid 10%). The early increment in reducing sugars may be because of converting the starch to reducing sugar and after that reducing process could be because of use of sugar in the respiration. The higher reducing sugar may be because of enhanced pace of starch degradation by activity of an enzyme called α amylase (Hiwale and Singh, 2003). Converting process of polysaccharides and starch to simple sugar with the progress of storing period was reason for the higher sugar of reducing nature.

Non-reducing sugar under cold condition

The range of non reducing sugar varied from 1.94 to 2.28%. The maximum value for non reducing sugar was 2.28% recorded for T6 (Oxalic Acid 5%) followed by T7 (Oxalic Acid 10%) i.e. 2.23%. The minimum value for non reducing sugar was 1.85% recorded for T0 (Control). As compared to T0, T6 showed 17.53% increase in non reducing sugar. The non-reducing sugar of litchi fruit remained unchanged or increased minutely or decreased minutely up to the end of storage periods. The higher content of non-reducing sugar in the experiment was observed in T7 (Oxalic Acid 10%). This increment in sugar at the initial of storage was mainly because of the hydrolysis of starch and lesser was because of the use of sugar in evaporation & transpiration and further activity of biochemistry. These observations are in accordance with the findings of Hiwale and Singh (2003) in guava as they also reported increase in sugar content during storage.

Total sugar under cold condition

The range of total sugar varied from 10.40 to 12.50%. The maximum value for total sugar was 12.50% recorded for T7 (Oxalic Acid 10%) followed by T6 (Oxalic Acid 5%) *i.e.* 12.41%. The minimum value recorded for total sugar was 11.65% recorded for T5 (Citric Acid 10%). As compared to T5, T7 showed 20.19% increase in total sugar. Results revealed that total sugar content of litchi fruits in the trail increased and continued up to the last

Table 8 : Effect of organic acids on total sugar (%) under cold storage conditions.

Treatment	Total Sugar (%)								
	Day 1	Day 3	Day 5	Day 7	Day 9	Day 11	Day 13	Day 15	Mean
T_0	11.70^{a}±0.017	11.73^{d}±0.020	11.75^{d}±0.023	11.75^{a}±0.011	11.79^{a}±0.011	11.80^{d}±0.006	11.85^{d}±0.026	11.87^{d}±0.023	11.78
T_1	12.19^{a}±0.012	12.22^{b}±0.014	12.25^{b}±0.014	12.28^{a}±0.012	12.30^{a}±0.012	12.32^{c}±0.012	12.34^{c}±0.012	12.36^{cd}±0.012	12.28
T_2	11.85^{a}±0.034	11.88^{d}±0.026	11.91^{d}±0.028	11.93^{a}±0.029	11.97^{a}±0.032	11.98^{cd}±0.027	12.01^{cd}±0.032	12.05^{d}±0.033	11.95
T_3	12.10^{ab}±0.017	12.12^{c}±0.014	12.15^{c}±0.017	12.18^{a}±0.017	8.14^{a}±0.070	12.24^{d}±0.017	12.26^{d}±0.017	12.26^{c} ±0.027	11.68
T_4	12.18^{b}±0.014	12.20^{b}±0.012	12.24^{d}±0.015	12.26^{a}±0.013	12.28^{a}±0.017	12.30^{c}±0.015	12.33^{c}±0.008	12.36^{cd}±0.008	12.27
T_5	10.88^{b}±0.066	10.24^{e}±0.020	10.27^{e}±0.017	10.30^{b}±0.017	10.33^{a}±0.020	10.36^{e}±0.023	10.39^{e}±0.032	10.41^{e}±0.032	10.40
T_6	12.37^{a} ±0.014	12.39^{a}±0.012	12.41^{b}±0.014	12.10^{a}±0.048	12.46^{a}±0.017	12.49^{b}±0.017	12.52^{b}±0.017	12.54^{b}±0.014	12.41
T_7	12.41^{a} ±0.016	12.44^{a}±0.006	12.49^{a}±0.005	12.19^{a}±0.033	12.56^{a}±0.010	12.60^{a}±0.008	12.63^{a}±0.009	12.66^{a}±0.012	12.50

Note : T0 (Control), T1 (Chitosan 1%), T2 (Ascorbic Acid 5%), T3 (Ascorbic Acid 10%), T4 (Citric Acid 5%), T5 (Citric Acid 10%), T6 (Oxalic Acid 5%), T7(Oxalic Acid 10).

day of storage. The highest per cent of total sugar was recorded with T7 (Oxalic Acid 10%) treatment. The increase in total sugar during storage might be because of an increase in reducing sugars and non-reducing sugars resulting conversion of starch into simple sugar and later on reduction in conversion rate was due to utilization of sugar in the process of respiration. Improvement in sugar per cent may be because of converting some cell wall material like hemicelluloses to reducing content under long storing conditions (Stahi and Camp, 1971). These results are in close similarity with the results of Parihar and Kumar (2007) because they found, total sugars were improved alongwith the higher storing period in guava.

Conclusion

From above findings, conclusion may be drawn that under cold storage condition, T1 (Chitosan 1%) treatment showed good results for most of the parameters. The chitosan act as anti-transparent coating for reducing respiration and transpiration rate. Chitosan contains anti-fungal properties, therefore, inhibits fungal growth to some extent and being an edible coating of polysaccharide does not possess any toxic affect to human health. Hence, to maintain quality maintenance and shelf life extension of litchi fruit, chitosan may help in formation of novel strategies that could be feasible for storage of litchi fruit on commercial scale. Results reveal that T1(Chitosan 1%) was most effective in reducing the rate of weight loss of litchi fruits under ambient conditions, while less weight loss in Trial II was recorded in T5(Citric acid 10%). However, the citric acid treatments failed to check the extent of browning in fruits, where fruits showed extensive browning and lost their consumer appeal after 9 days of storage under cold conditions.

References

Chandel, S. K. (1987). Effect of some pre-harvest factors on the cracking, yield and post-harvest changes in the quality of litchi fruits (*Litchi chinensis* Sonn.) cv Rose Scented. *M. Sc.(Ag.) (Doctoral dissertation)*, Thesis in Horticulture, submitted to GBPUA 8 T, Pantnagar).

Gaur, G. S. and P. N. Bajpai (1978). Post harvest physiology of litchi fruits. I. *Progressive Horticulture*, **10(3)** : 63-77.

Ghosh, U., A. Bhattacharjee, P. K. Bose, D. R. Choudhuri and H. Gangopadhyay (1998). Physicochemical changes of litchi in modified atmospheric storage. *Indian Journal of Chemical Technology*, **5** : 393-396.

Hiwale, S. S. and S. P. Singh (2003). Prolonging shelf-life of guava (*Psidium guajava* L.). *Indian Journal of Horticulture*, **60(1)** :1-9.

Huang, P. Y. and K. J. Scott (1985). Control of rotting and browning of litchi fruit after harvest at ambient

temperatures in China. *Tropical Agriculture*, **62(1)** : 2-4.

Jiang, Y. and Y. Li (2001). Effects of chitosan coating on postharvest life and quality of longan fruit. *Food Chemistry*, **73(2)** : 139-143.

Jiang, Y., J. Li and W. Jiang (2005). Effects of chitosan coating on shelf life of cold-stored litchi fruit at ambient temperature. *LWT-Food Science and Technology*, **38(7)** : 757-761.

Jiang, Y. M. and Y. B. Li (2003). Effects of low-temperature acclimation on browning of litchi fruit in relation to shelf life. *The Journal of Horticultural Science and Biotechnology*, **78(4)** : 437-440.

Jiang, Y. M., L. Yao, A. Lichter and J. R. Li (2003). Postharvest biology and technology of litchi fruit. *J. Food Agric Environ*., **1(2)** : 76-81.

Kumar, A. (2000). Effect of foliar sprays of multi-K on yield quality and shelf life of litchi (*Litchi chinensis* Sonn.) cv. Rose Scented (*Doctoral dissertation, Thesis, M. Sc.(Ag.)*, Horticulture. GB Pant University of Agric.And Tech., Pantnagar).

Mahajan, B. V. C. (1997). Studies on the bio-chemical changes in litchi fruits during storage. *Indian Journal of Plant Physiology*, **2** : 310-311.

Mahajan, B. V. C., A. S. Dhatt, R. K. Dhall and R. C. Sharma (2003). Effect of sulphur dioxide fumigation on the colour retention and quality of litchi cv. Calcuttia during cold storage. *Haryana Journal of Horticultural Sciences*, **32** : 47-49.

Mapson, L. W. (1970). Vitamin in fruits. *The biochemistry of fruits and their products*, **1** : 369-386.

Menzel, C. (2001). The physiology of growth and cropping in lychee. *South Afr. Litchi Grow. Assoc*. Yearbook, **12**: 9-14.

Misra, R. S. and I. Khan (1981). Effect of 2, 4, 5-trichlorophenoxyacetic acid and micronutrients on fruit size cracking, maturity and quality of litchi cv. Rose Scented. *Progressive Horticulture*. **13(3-4)** : 87-90.

Pantastico, Er. B. (1975). Post-harvest physiology, handling and utilization of tropical and sub-tropical fruits and vegetables.AVI Publishers. West Port, Connecticut, 560p.

Rai, D. R., H. S. Oberoi and B. Baboo (2002). Modified atmosphere packaging and its effect on quality and shelf life of fruits and vegetables: An overview. *Journal of Food Science and Technology*, **39(3)** : 199-207.

Rattanapanone, N., A. Plotto and E. Baldwin (2007). Effect of edible coatings and other surface treatments on pericarp color of Thai Lychee cultivars. In : *Proc. Fla. State Hort. Soc*., **120** : 222-227.

Rawat, B. S. (2001). Effect of foliar application of water soluble fertilizers, multi-K and polyfeed on yield, quality and shelf life of litchi (*Litchi chinensis* Sonn.) cv. Rose Scented. *M. Sc.(Ag.) Horticulture Thesis*, GB Pant University of Agri. & Tech., Pantnagar.

Ray, P. K., R. Rani and S. K. Singh (2004). Effect of temperature and sulphur treatments on storage behaviour of litchi fruits. *Indian Journal of Horticulture*, **61(4)** : 292-295.

Santerre, C. R., J. N. Cash and D. J. Vannorman (1988). Ascorbic acid/citric acid combinations in the processing of frozen apple slices. *Journal of Food Science*, **53(6)** : 1713-1716.

Sapers, G. M., K. B. Hicks, J. G. Phillips, L. Garzarella, D. L. Pondish, R. M. Matulaitis, T. J. McCormack, S. M. Sondey, P. A. Seib and Y. S. Ei Atawy (1989). Control of enzymatic browning in apple with ascorbic acid derivatives, polyphenol oxidase inhibitors and complexing agents. *Journal of Food Science*, **54(4)** : 997-1002.

Semeerbabu, M. T., V. B. Kudachikar, B. Revathy and A. Ushadevi (2007). Effect of post-harvest treatments on shelf-life and quality of litchi fruit stored under modified atmosphere at low temperature. *Journal of Food Science and Technology, India*, **44(1)** : 107-109.

Sivakumar, D. and L. Korsten (2006). Evaluation of the integrated application of two types of modified atmosphere packaging and hot water treatments on quality retention in the litchi cultivar 'McLean's Red'. *The Journal of Horticultural Science and Biotechnology*, **81(4)** : 639-644.

Sivakumar, D., T. Regnier, B. Demoz and L. Korsten (2005). Effect of different post-harvest treatments on overall quality retention in litchi fruit during low temperature storage. *The Journal of Horticultural Science and Biotechnology*, **80(1)** : 32-38.

Yonemoto, Y., H. Higuchi and Y. Kitano (2002). Effects of storage temperature and wax coating on ethylene production, respiration and shelf-life in cherimoya fruit. *Journal of the Japanese Society for Horticultural Science*, **71(5)** : 643-650.

Zhang, D. and P. C. Quantick (1997). Effects of chitosan coating on enzymatic browning and decay during postharvest storage of litchi (*Litchi chinensis* Sonn.) fruit. *Postharvest Biology and Technology*, **12(2)** : 195-202.