POST-HARVEST QUALITY IMPROVEMENT OF LITCHI FRUIT BY COMBINE APPLICATION OF NITRIC ACID, OXALIC ACID AND ASCORBIC ACID UNDER COLD STORAGE CONDITION

Umar Hayat[1*], Ijaz Hussain[1], Cao Ke[3], Waseem Ahmed[1], Syed Ehtasham Amin[4] ,Muhammad Abbas Khan[2], Sohail Aslam[2], Sughra Bibi[6], Qasim Ayub[1], Akhi Badrunnesa[8], Shahzad Haider[7], Alexander Yesaya[5], Qingtao Wang[3]

[1]*Department of Horticulture, The University of Haripur, Pakistan.*
[2]*National Tea and High Value Crops Research Institute, Shinkiari.*
[3] *Zhengzhou Institute of fruit trees, Chinese Academy of Agriculture Sciences Zhengzhou 450009, China.*
[4]*Department of Food Science and Technology,, The University of Haripur, Pakistan.*
[5]*Department of Crop & Soil Sciences, Lilongwe University Of Agriculture & Natural Resource Malawi..*
[6]*Department of Chemistry, Hazara University Mansehra, Pakistan.*
[7]*Department of Agronomy, The University of Haripur, Pakistan.*
[8] *Department of Agronomy, Sher-e-Bangla Agricultural University Bangladesh.*

Abstract

Pericarp browning is the primary cause of degradation in harvested litchi fruit. Water loss causes pericarp browning in litchi fruit. Present research was carried out to examine the effects of combine application of Nitric acid, Oxalic acid and Ascorbic acid on post-harvest quality of litchi fruit under cold storage. The study was conducted at Horticulture laboratory in 'The University of Haripur' during 2019. Fruits of Litchi cv. 'Bedana' were dipped in different combination of Nitric acid, Oxalic acid and Ascorbic acid which were T1=0.5% nitric acid+1% oxalic acid + 1% ascorbic acid, T2=1% nitric acid + 2% oxalic acid + 2% ascorbic acid and T3=1.5% nitric acid + 3% oxalic acid + 3% ascorbic acid for 15 minutes. After the application of treatments fruits were kept for 12 days under cold storage at temperature of 4±1 ℃. Data on different parameters was recorded after regular interval of 3 days. Results indicated that combine application of 1.5% nitric acid + 3% oxalic acid + 3% ascorbic acid decreased weight loss (3.6%), browning index (27.4%), fruit decay (0.0%), pH (5.3) and TSS (12.4 Brix°); while an increased in vitamin-c (43.8 mg 100 mL^{-1}) were recorded. Whereas untreated fruits (control) demonstrated an increased in weight loss (5.9%), browning index (34.1%), fruit decay (4.7%), pH (5.4) and TSS (12.7 Brix°). Therefore, it can be concluded that combine application of 1.5% nitric acid + 3% oxalic acid + 3% ascorbic acid successfully enhances the post-harvest quality of fruits under cold storage.

Keywords; Litchi, Anti-oxidants, Post-harvest, Cold storage.

Introduction

Litchi (*Litchi chinensis*) is a tropical fruit belongs to the family *Sapindaceae*. It has been cultivated since 1766 B.C (Jana *et al*., 2019). The fruit is surrounded by a reddish pericarp, which is around 1-3mm thick and covers the watery translucent pulp. Litchi is a climacteric fruit and shows higher rates of reparation and continues to ripen after harvesting. The higher water content also makes litchi fruit to postharvest decay and diseases attack which makes storage duration of litchi very short (Ali *et al*., 2018). The estimated post-harvest losses during storage are up to 25 to 35% and can reach above 50% before reaching to consumers (Wu *et al*., 2011). The concentration of bioactive compounds decreases rapidly after harvesting (Anmol 2018). Another problem is the browning of litchi fruits after harvest in which fruit peel start to change color with in the first 24 hours and fruit peel begins to turn from red to brown (Zheng and Tian, 2006). The litchi red peel color is one of the key features for determining the commercial output of litchi (Reichel *et al*., 2013). Rapid, humidity-related pericarp browning decreases value, and creates severe transportation and marketing problems for litchi fruits, as pericarp transforms it entirely from round to brown within days of harvest (Rajwanshi *et al*., 2017). Browning of litchi has primarily been attributed to red pigment loss (anthocyanin) and the undermining of polyphenol oxidase (PPO) and peroxidase compounds (Xiao *et al*., 2019). Due to unique physiology of litchi fruit the lack of water supply to pericarp from pulp also plays a role in browning of litchi fruit. The water loss also reduces antioxidant potential and increases phenolic oxidation (Xiao *et al*., 2019). The cell's pH, which influences the structure, stability and color of anthocyanin enzymes and thus contributes to pericarp browning is also enhanced by water loss (Fang *et al*., 2013). Meanwhile, micro cracking happened on the thin skin surface with fruit maturation and senescence, which alsosped up depletion of water (Barman *et al*., 2014).

Many different method and new techniques are being implemented and tried by scientists to reduce the post-harvest damages in litchi fruit. Use of human and environment friendly chemicals like Oxalic acid, Nitric acid and Ascorbic acid is one of them. These chemicals naturally occur as organic acid and preserve membrane integrity and slow fruit to ripen (Dahiya *et al*., 2010). Post- harvest use of oxalic acid has been shown to postpone ripening and preserve post-harvest consistency of different fruits and vegetables by slowing the development, respiration and output of active oxygen species, thereby enhancing antioxidant capacity (Razzaq *et al*., 2015). It also reduces chilling injury in peach, mango and tomato (Razavi *et al*., 2017), regulates browning of litchi fruit (Zheng and Tian, 2006) and reduces decay in jujube and mango (Wang *et al*., 2009). Nitric oxide is mainly described as free radical gas that plays a role as a various functional signaling molecules in both animals and plants (Bot *et al*., 2019). It is used to regulate a range of developmental and physiogical processes in plants (Asgher *et al*., 2017), it is anti-sensitivity and anti-ripening by action and controls respiration rate, disease occurrence, ethylene biosynthesis, delayed rind color changes, and turn out in minimization of enzymatic activities (Duan *et al*., 2007). Vitamin C or Ascorbic acid (AA), an antioxidant, is beneficial for inhibiting browning reactions (Niu *et al*., 2019). By forming ascorbyl, it directly stores harmful radicals (Moghimi *et al*., 2018) and decreases o-quinones formed by Polyphenol oxidase to phenolic substrates. Being an antioxidant, it regulates the development of micro-organisms that render food spoilage (Hashemabadi *et al*., 2018).

It is of utmost importance to preserve the post-harvest quality and appeal of litchi fruit during storage and marketing in order to do so; many methods and techniques are being implemented by scientist which includes use of

various human-friendly chemicals. Effectiveness of Oxalic Acid, Nitric acid and Ascorbic Acid has been studied extensively on various fruits and vegetables, but major limitation of these studies is that they only used either one of the above mentioned chemical. So this study was designed to study the combine effects of Oxalic Acid, Nitric acid and Ascorbic Acid on litchi fruit during storage and marketing. Hence this study was undertaken to study the effect of different storage durations (Cold storage) and to investigate the effectiveness of different combinations of Oxalic acid, Nitric acid and Ascorbic acid to enhance shelf life and post-harvest quality of litchi fruits.

Materials and Methods

Present study was designed and exhausted at Horticulture Lab, The University of Haripur, Pakistan during the mouths of August to September 2019. The experiment was performed in Completely Randomized Design (CRD). Ripped and unripe fruits of litchi cultivar Badana were harvested from orchards of Khanpur, Pakistan and were transported to laboratory in cardboard boxes. Fruits were washed vigorously with tape water to eliminate foreign particles and microbial load. Washed and dried litchi fruit were then treated with Nitric acid, Oxalic acid and Ascorbic acid. The treatment combinations were; T0= Control, T1= 0.5% nitric acid + 1% oxalic acid + 1% ascorbic acid, T2= 1% nitric acid + 2% oxalic acid + 2% ascorbic acid, T3= 1.5% nitric acid + 3% oxalic acid + 3% ascorbic acid. Each treatment was replicated three times with 21 fruits in each replication. Each batch of litchi fruits was dipped for 15 minutes in solution and for the treatment of next batch used solutions were replaced by new solutions. After application of treatments litchi fruits were kept under cold storage at temperatures of 2±4°C for 12 days. Data regarding different parameters were taken on regular interval of three days i.e. on 0day, 3rd day, 6th day, 9th day and on 12th day. Data regarding weight loss, browning index, juice pH, total soluble solids, Titratable acidity and vitamin-c content was recorded during the study.

Fruit weight loss (%)

The digital balance (MJ-W176P, Panasonic Japan) was used to measure the weight of fruit prior to and after storage. The percentage weight loss of fruits was determined with next to formula

$$\text{Fruit weight loss (\%)} = \frac{\text{Fresh weight} - \text{Weight after storage}}{\text{Fresh weight}} \times 100$$

Browning index ;

Pericarp browning was measured on the basis of visual scale as reported by Jiang & Chen (1995) (Table-1). For marketing, fruit lots with a pericarp browning index greater than 3.0 were deemed undesirable.

Table 1 Scale used for quality assessment

Pericarp browning index
1 = 0. (excellent quality) no browning
2 = 1. (good quality) slightly browning
3= 2. < ¼ browning
4= 3. ¼ to ½ browning
5= 4. > ½ to ¾ (poor quality) browning
6 = 5. > ¾ (very poor quality) browning

Decayed fruits ;

Total number of decayed fruits from each treatment was counted.

$$\text{Fruit decay (\%)} = \frac{\text{Decayed fruits}}{\text{Total number of fruits}} \times 100$$

Total soluble solids, titratable acidity and ascorbic acid;

A 20 g sample of pulp from 10 fruit was homogenized in a grinder and centrifuged at 20,000 rpm for 15 min. Supernatant was collected to determine the contents of total soluble solids, titratable acidity and ascorbic acid Nagar, 1994. pH of the litchi fruit juice was measured with digital pH meter (HI 98107, Hanna, Mauritius at 18ºC±2ºC). The pH meter was adjusted and 60 ml of juice sample were then put in the clean 100ml of beaker to record the reading. Total soluble solid was measured by hand-holder refractometer (KROSS HRN-16) and presented in Brixº. Refractometer was set to a zero reading by using distilled water. The prism plate of the refractometer was loaded with a single drop per sample of fruit juice. After taken each reading prism plate was washed with distilled water and a dried with soft tissue. 10mL of litchi juice was extracted and mixed with 100mL distilled water in a conical flask. Then the solution was titrated against 0.1N NaOH. The solution was then used to suggest 2-3 drops of the phenolphthalein before pink was seen. To evaluate TA calculations, the main acid in the litchi at maturity was 0.067 (Huang and Scoot, 1985), using the thousand equivalent factor for malic acid. The proportion was then determined using the formula as follows:

TA (%) = 0.1 NaOH used x 0.067 × 100 mL of juice used

The process defined by Ruck,1969 was carried out for the estimation of Vitamin-C in the juice. The juice collected from each sample has been filtered with Whatman filter paper for this reason. Filtered aliquot of ten ml was taken in 100 mL of volumetric flask and then through addition of 0.4 percent oxalic acid the volume was raised.

Then 5 ml of 100 mL aliquot was taken in a beaker and titrated against the newly prepared dye (2,6-dichlorophenol indophenol) until the pink light end stage, 10-15 seconds long, emerged. The following formula was then used to measure ascorbic acid:

$$\text{Vitamin-C (mg 100 mL}^{-1}) = \frac{D1 \times V}{D \times A \times B} \times 100$$

Where,

D1= Used mL dye for aliquot titration.

D = Used mL dye for the titration of 1 mL standard solution of ascorbic acid prepared by additionof 1 mL of 0.1 % ascorbic acid along with addition of 1.5 mL of 0.4% oxalic acid.

A= Used mL of juice

V= Aliquot volume made by the addition of oxalic acid 0.4%.

B= Aliquot mL used for titration

Preparation of dye

Dye was prepared in a 200 ml volumetric flask through addition of 42 mg $NaHCO_3$ and 52 mg 2, 6-dichlorophenol indophenols. Distilled water, filtered and often freshly prepared colouring was used to the label

Statistical Analysis

Statistic 8.1 was used for two-factor (treatments and storage days) factorial structures for window software, including treatments and fruit storage time. The experimental findings were analyzed for variation (ANOVA). Two fruit with three replicates have been considered per experimental device. The results of counseling have been measured from the (Fisher, s) LDC test at $p < 0.05$ with a significant f test (Steel et al., 1997).

Results and Discussion

Table-1; Effect of Oxalic Acid, Nitric Acid and Ascorbic Acid treatments and cold storage on post-harvest quality of Litchi fruit

Treatments	*WL*	*BI*	*FD*	*pH*	*TSS*	*TA*	*AA*
Control	5.9 a	34.1 a	4.7 a	5.4 a	12.7 a	10.2 a	44.1 a
T1	4.3 b	31.6 b	0.0 b	5.3 b	12.5 b	9.5 a	43.8 a
T2	4.2 c	30.5 c	0.0 b	5.3 b	12.5 b	10.2 a	43.8 a
T3	3.6 d	27.4 d	0.0 b	5.3 b	12.4 c	9.4 b	43.8 a
LSD	***0.1293***	***0.4600***	***0.1871***	***0.0377***	***0.0459***	***0.2998***	***0.9070***
Storage Duration							
SD1	0.0 e	0.0 e	0.0 c	4.2 e	9.6 e	10.6 a	47.7 a
SD2	4.5 d	18.9 d	0.0 c	4.6 d	10.6 d	10.6 a	47.7a

SD3	5.1 c	34.3 c	0.0 c	5.2 c	12.5 c	8.6 c	45.2 b
SD4	5.8 b	46.5 b	2.4 b	6.0 b	14.4 b	9.8 b	42.0 c
SD5	7.1 a	54.7 a	3.5 a	6.7 a	15.4 a	9.5 b	36.8 d
LSD	***0.1446***	***0.5142***	***0.2091***	***0.0422***	***0.0513***	***0.3352***	***1.0141***
LSD* T×SD	***0.2892***	***1.0285***	***1.4183***	***0.0844***	***0.1026***	***0.6703***	***2.0282***

WL*= weight Loss;* ***BI****=Browning index,* ***FD****=Fruit Decay;* ***TSS****=Total Soluble Solids,* ***TA****= Titratable acidity;* ***AA****=Ascorbic Acid*

Weight loss (%)

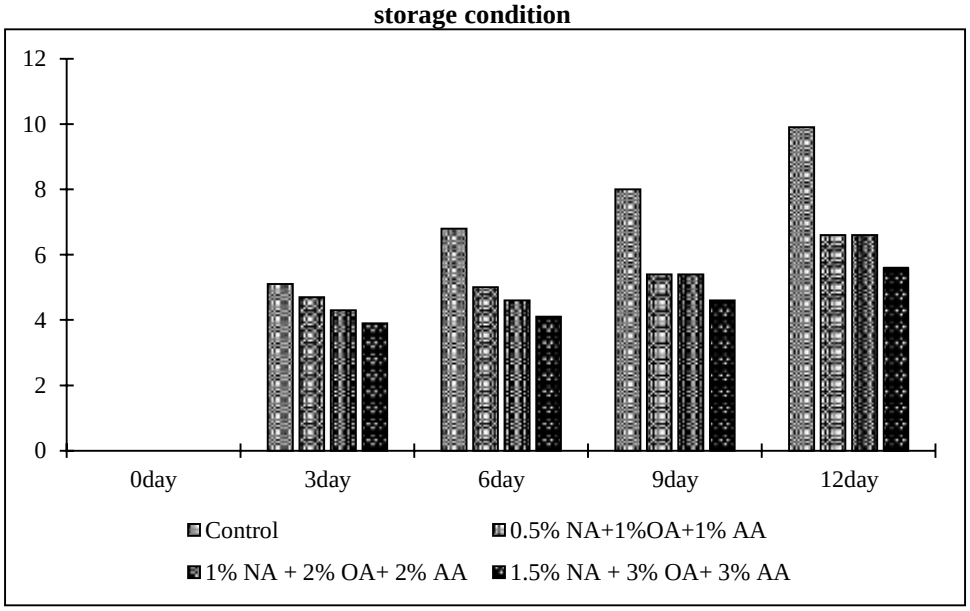
Analysis of variance regarding weight loss percentage showed that highly significant difference ($p<0.01$) exists between applied treatment, storage durations and their interaction.

An increasing trend was recorded for weight loss for storage duration. The Maximum weight losses (7.1%) were recorded at 12th storage day, while least reduction in weight (0.0%) was recorded in 0 storage day. Highest weight loss (5.9%) was recorded in T0 where lowest weight loss (3.6%) was recorded in T3 (Table-1). The interaction of treatment and storage showed that maximum weight loss (9.9%) was recorded in 12th storage day in fruits which were kept under control, whileleast reduction in weight (0.0%) at T3 and on0 Storage day (Figure 1).

Tendency of weight loss with increase in time period was also confirmed by Mitra and Kar (2001) in litchi cv. 'Bombai'. Untreated fruit showed highest weight loss irrespective to cultivars. Probable when cold storage days increased the weight loss of the fruits significantly increased. The weight loss of treated fruits increases is mainly due to the moisture loss by transpiration, respiration and there are other several metabolic activities in the fruit taking place with the progression of cold storage duration (Narayana *et al*., 1996). Though, in current study lesser weightloss with evolution of cold storage may be attributed to the combine application effect of 1.5%

nitric acid, 4% oxalic acid and 4% ascorbic acid solution. Combine applications of these treatments reduce moisture loss by isolating the pericarp from the outer environment (Khan et al., 2020).

Figure-1 Effect of Oxalic Acid, Nitric Acid and Ascorbic Acid on Weight loss (%) of Litchi fruit under cold storage condition



Browning index (%)

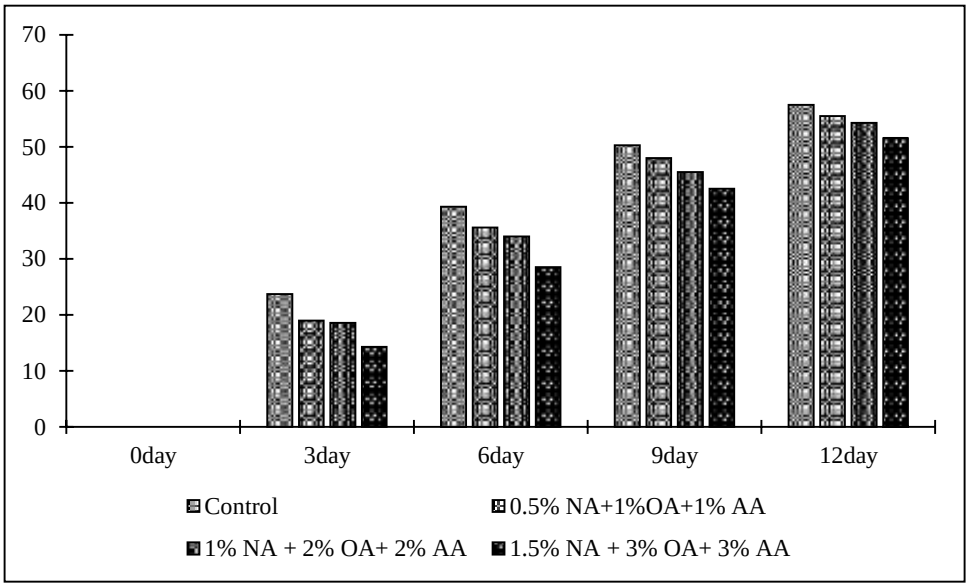
Analysis of variance regarding browning index percentage showed that highly significant difference ($p<0.01$) exists between applied treatment, storage durations and their interaction (Table 1).

Data relating to browning index reveled that maximum browning index (34.18%) was recorded in T0, where minimum browning index (27.40%) was noted in T3. An increasing pattern for browning index was noted for storage duration. The highest browning index (54.75%) were recorded at 12th storage day, while least reduction in browning (0.00%) was recorded in 0storage day and (18.94%) in 6th storage day (Table-1). The interaction of treatment and storage showed that highest browning index (57.50%) was recorded in storage day 12th in fruits which were kept under control, while least reduction in browning index (0.00%) at T3 0 n 0 Storage day (Figure 2).

Similar findings were observed by Jaos *et al*., (2005) in litchi cultivar 'KwaiMi' Continuous rise in litchi browning was revealed by increase in fruit weight loss. The increase in the activities of peroxidase and polyphenol oxidase causes the pericarp browning. After harvest, at the time of cold storage period litchi fruit suffer stress by breakdown of cell membrane, moisture loss and improved the action of polyphenol oxidase. When PPO comes in contact with anthocyanin in presence of oxygen, the anthocyanin undergoes irreversibly broken down into melanin by-products causing pericarp browning (Lin *et al*., 2002). The application of T3 1.5% nitric acid, 4% oxalic acid and 4% ascorbic acid performed well against litchi pericarp browning as compared to other treatments,

these chemicals might have reduced the activities of PPO and POD enzymes in the pericarp and reduces the process of pericarp browning.

Figure-2 Effect of Oxalic Acid, Nitric Acid and Ascorbic Acid on Browning Index (%) of Litchi fruit under cold storage condition



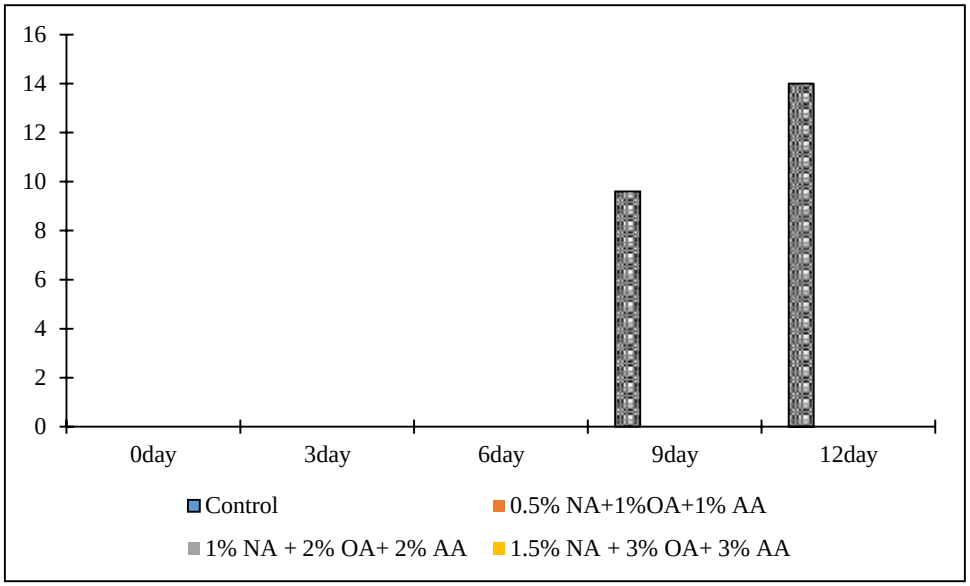
Fruit Decay (%)

Analysis of variance regarding fruit decay percentage showed that highly significant difference ($p<0.01$) exists between applied treatment, storage durations and their interaction (Table 1).

An increase was recorded for fruit decay during the storage duration. The highest fruit decay (3.50%) was noted at 12thstorage day, whereas lowest reduction in fruit decay (0.00%) was observed in 0, 3rd and 6th storage day. Results regarding fruit decay indicate that highest fruit decay (4.73%) was recorded in T0 where lowest fruit decay (0.00%) was obtained by T1, T2 and T3 (Table-1). The interaction of treatment and storage showed that highest fruit decay (14%) was recorded in 12th storage day in untreated litchi fruits, while least reduction in fruit decay (0.00%) at were observed in T1, T2 and T3 at 0, 3rd and 6th Storage day (Figure 3).

Litchi fruits treated with T1 (0.5% nitric acid, 1% oxalic acid and 1%ascorbic acid), T2 (1% nitric acid, 2% oxalic acid 2% and 2%Ascorbic Acid) and T3 (1.5 % nitric acid, 3% oxalic acid and 3% ascorbic acid) showed the minimum fruits decay as compared to control fruits. The expansion in storage duration caused the fruits decay in litchi (Nigam and Kumar, 2001). The oxalic acid contained the fungi static characteristics which may help to the less decay of litchi fruits (Sivakumar *et al*., 2005). Acidic surroundings on the rind surface make it hard for the majority ofthe fungi to expand (Lichter *et al*., 2004).

Figure-3; Effect of Oxalic Acid, Nitric Acid and Ascorbic Acid on Fruit decay (%) of Litchi fruit under cold storage condition



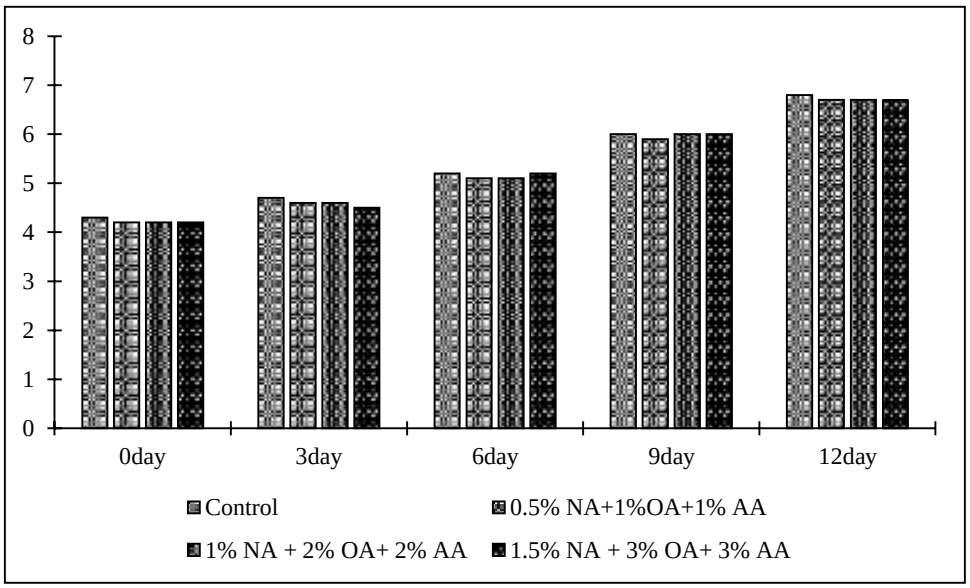
pH of Fruit Juice

Analysis of variance regarding Juice pH showed that highly significant difference ($p<0.01$) exists between applied treatment and storage durations, whereas the interaction of treatment and storage durations were non-significant ($p>0.05$) (Table 1).

pH of litchi fruit juice exhibited an increasing pattern during storage period. It was noted that maximum pH (6.75) was recorded during 12thstorage duration, while least pH (4.291) was recorded in 0 storage day. The results of the study indicated that application of different treatments have imparted a reduction in juice pH and lowest values of pH (5.36) were recorded T1 while untreated fruits showed maximum pH (5.46) (Table-1). The interaction of treatment and storage showed that highest Juice pH (6.83) was recorded in storage duration 12th in fruits which were kept under control, while least reduction in Juice pH (4.26) at T3 and Storage duration 0 (Figure 4).

Storage has been known to change a pH of stored fruits as storage of foods may alter the pH of the Fruit juice due to Ionization of molecules like H_2O has been reported under storage which increases the Hydrogen ion concentration thus lowering the pH of the food (Heremans, 1995). In general, the solubility of most natural compounds increases under during storage Increase in pH during storage might be due to ripening changes in fruit, whereas subsequent decrease may have resulted from decay during storage (Aklimuzzaman *et al*., 2011; Khan *et al*., 2012).

Figure-4 Effect of Oxalic Acid, Nitric Acid and Ascorbic Acid on Juice pH of Litchi fruit under cold storage condition



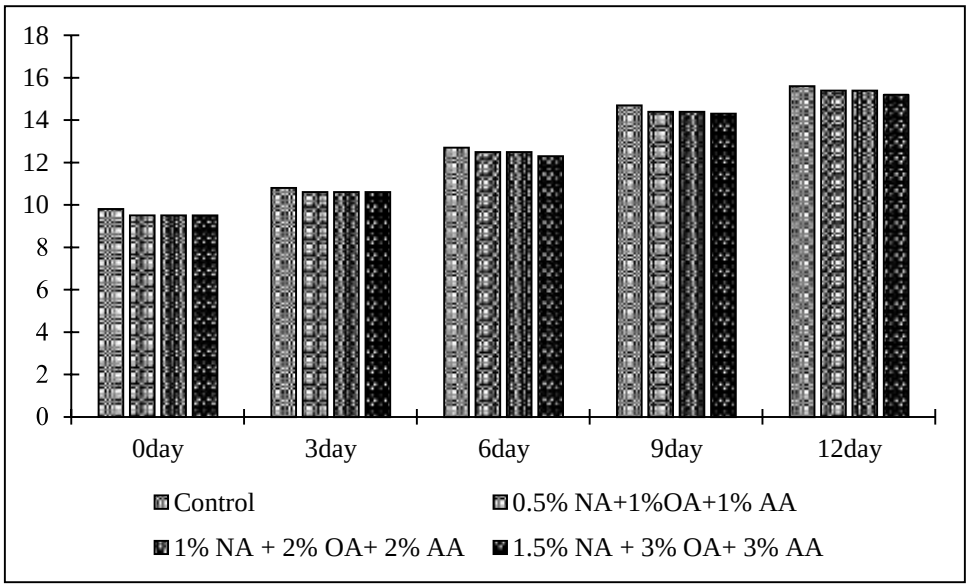
Total Soluble Solid (Brix°)

Analysis of variance regarding Total Soluble Solid (Brix°) showed that highly significant difference ($p<0.01$) exists between applied treatment and storage durations, whereas the interaction of treatment and storage durations were non-significant ($p>0.05$) (Table 1).

An increasing trend was recorded for total soluble solid for storage duration and at 12th day of storage maximum total soluble solid (15.45 Brix°) were recorded while lowest values of total soluble solid (9.61 Brix°) was recorded during 0 storage day. Highest total soluble solid (12.74 Brix°) was recorded in control whereas lowest total soluble solid (12.42 Brix°) was recorded in T3 (Table-1). The interaction of treatments and storage showed that highest total soluble solid (15.63Brix°) was recorded in 12thstorage day in fruits which were kept under control, while least reduction in total soluble solid (9.53 Brix°) in T3 on 0 Storage day (Figure 5).

Rise in total soluble solids is due to increase in cold storage interval by towering water mislay, these results were also reported in grapes berries by Tanada-Palmu and Grosso (2005). Results also accord with Aklimuzzaman *et al*., (2011) who noticed rise in TSS is due to storage duration in litchi cultivar 'Bedana'. Control fruits revealed raise in total soluble solid analogous results reported by Chema *et al*., (2014) who noticed that there were raise in TSS (4.1-4.5 Brix°) of control and the treated tomato fruit with hexanal at the time of cold storage duration. Ali *et al*., (2021) supported the argument that concentration of SSC might be increased in pulp tissue in litchi fruit cultivar 'Bedana' and 'Shahi'' because of Moisture loss during cold storage in such order. Tanada- Palmu and Grosso (2005) also reported the same trend for TSS in grapes berries fruits.

Figure-5; Effect of Oxalic Acid, Nitric Acid and Ascorbic Acid on Total soluble solid (Brix°) of Litchi fruit under cold storage condition



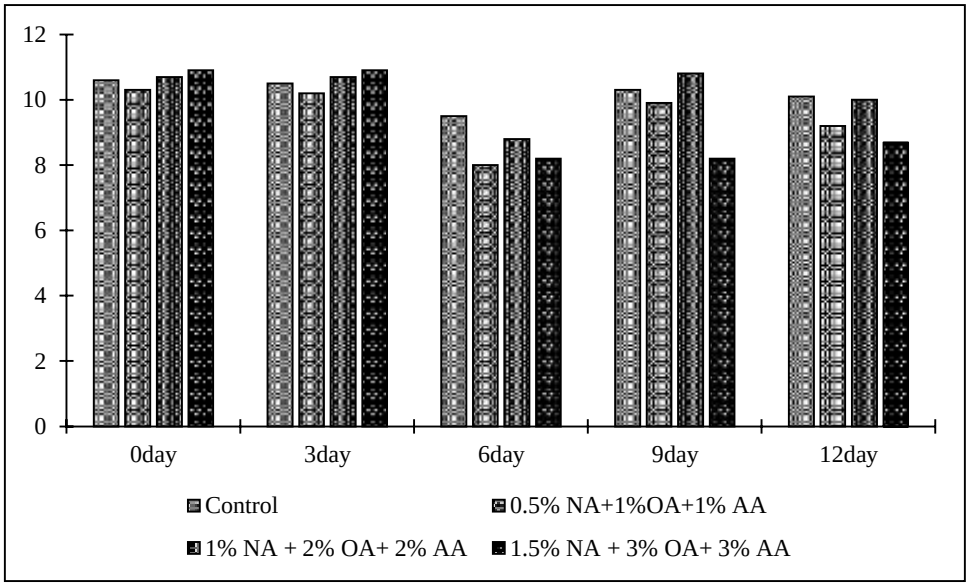
Titratable acidity (%):

Analysis of variance regarding Titratable acidity percentage showed that highly significant difference ($p<0.01$) exists between applied treatment, storage durations and their interaction (Table 1).

A decreasing trend was recorded for titratable acidity for storage duration. The maximum titratable acidity (10.66%) was recorded at 0 storage day, while least reduction in titratable acidity (8.76%) was recorded in 6thstorage day. Data regarding titratable acidity observed that total titratable acidity (10.26%) was recorded in T0 where lowest total titratable acidity (9.43%) was recorded in T3 (Table-1). The interaction of treatment and storage showed that highest titratable acidity (10.96%) was recorded in storage day 0 in fruits which were kept under control, while least reduction in titratable acidity (8.06%) at T1 and Storage day6th (Figure 6).

Litchi fruits treated with T3 (1.5% nitric acid, 4% oxalic acid and 4% ascorbic acid) preserved maximum level of titratable acidity under cold storage as related to control. This was due to the fact that T3 might have delayed the ripening and senescence process of fruit. Numerous researcher described the antagonistic effect between NO and ethylene (Ku *et al*., 2000). NO binds with the ACC oxidase enzyme to form ACC oxidase–NO complex, which more chelated by ACC and produces more stable ACC–ACC oxidase–NO complex, thus falling the biosynthesis of ethylene (Manjunatha *et al*., 2010). Furthermore, delayed senescence process in T3 treated fruit may be attributed to anti-senescence property of NO which delayed the respiration rate of stored fruit, thus reducing breakdown of sugars in the food matrix (Barman *et al*., 2011). The dominance of respiration rate in NO-treated fruit during ripening has also been described in fruits like mango (Zaharah and Singh, 2011), strawberry (Zhu et al.,2009), plum (Singh *et al*., 2009) and peach (Flores *et al*., 2008).

Figure-6; Effect of Oxalic Acid, Nitric Acid and Ascorbic Acid on Titratable acidity (%) of Litchi fruit under cold storage condition



Ascorbic acid content (mg 100 mL^{-1}):

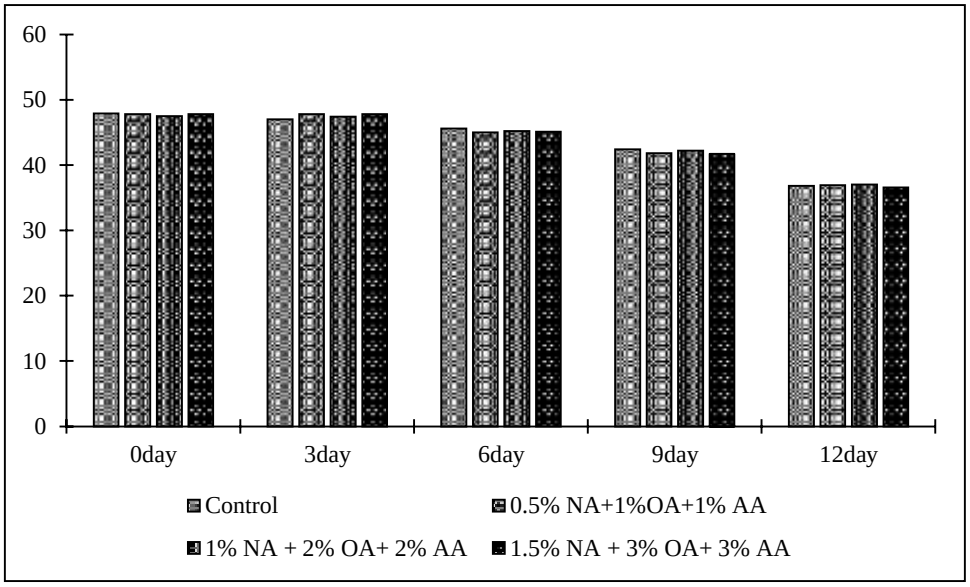
Analysis of variance regarding Vitamin C (mg 100 mL^{-1}) revealed that highly significant difference ($p<0.01$) exists between storage durations, whereas applied treatment and the interaction of storage durations and applied treatment were non-significant ($p>0.05$) (Table 1)

A decreasing trend was recorded for Vitamin-C during the storage of litchi fruits. The maximum Vitamin-C (47.76 mg ml^{-1}) was recorded at 0 storage day, while at 12^{th} storage day least values of Vitamin-C (36.85 mg ml^{-1}) were recorded. Results regarding treatment application indicated that maximum Vitamin c (44.15mg ml^{-1}) was observed in T0 whereasT3 produced lowest vitamin c(43.85mg ml^{-1}) (Table-1). The interaction of treatment and storage showed that highest vitamin c (47.91mg ml^{-1}) was recorded on 0 storage day in fruits which were kept under control, while leastreduction in vitamin-c (36.67 mg ml^{-1}) was produced by T3 during 12^{th}Storage day (Figure 7).

Decline in Vitamin-C probably attributed to dissimilar metabolic changes and respiration in fruit that cause in exchange of organic acid into sugars (Gimnez *et al*., 2003). Apart from it, oxalic acid inhibited the lipid peroxidation and work as a natural antioxidant as a result, eventually declines the oxidation of Vitamin-C (Kayashima and Katayama, 2002). Related results were revealed by Chema *et al*., (2014) who observed that control and T1 who was the combination of (0.5 % Nitric Acid, 1% Oxalic Acid and 1% Vitamin-C) treated litchi fruit hold maximum Vitamin-C contents (44.15 and 43.89 mg g-1) as related to the T2 (1 % Nitric Acid, 2% Oxalic Acid and 2% Vitamin-

C) and T3 (1.5 % Nitric Acid, 3% Oxalic Acid and 3% Vitamin-C) (43.88 and 43.88 mg g-1) after21 days of storage.

Figure-7 Effect of Oxalic Acid, Nitric Acid and Ascorbic Acid on Ascorbic acid (mg 100 mL^{-1}) of Litchi fruit under cold storage condition



Conclusion

In conclusion, the application of 1.5% nitric acid, 3% oxalic acid, and 3% ascorbic acid demonstrated to be an efficient treatment for enhancing the post-harvest quality of litchi fruit while stored in cold storage. Weight loss, browning index, and fruit decay—three important parameters impacting fruit quality during storage—were all significantly reduced by this type of treatment. In addition, compared to the untreated control, the treated fruits revealed higher pH and TSS levels. Notably, the treated fruits had much more vitamin C content than untreated (control) fruits, which indicates the fruits had better nutritional value.

The findings of this study demonstrate the possibility of using nitric acid, oxalic acid, and ascorbic acid in combination as a post-harvest treatment to improve the quality and shelf life of litchi fruit under cold storage. This technique can be suggested to growers and fruit handlers as an effective and environmentally responsible way to reduce post-harvest losses and preserve the fruit's appearance, flavor, and nutritional value. The application of these acids to additional fruit types and an evaluation of their long-term effects on fruit quality and safety could be the subject of future study.

References

Aklimuzzaman, M., Goswami, C., Howlader, J., Kader, H.A. and Hassan, K., 2011. Postharvest storage behavior of litchi. *JOURNAL Of Horticulture, Forestry And Biotechnology*, *15*(3), pp.1-8.

Ali, S., Khan, A.S., Malik, A.U., Shaheen, T. and Shahid, M., 2018. Pre-storage methionine treatment inhibits postharvest enzymatic browning of cold stored 'Gola'litchi fruit. *Postharvest Biology and Technology*, *140*, pp.100-106.

Barman, K., Asrey, R. and Pal, R.K., 2011. Putrescine and carnauba wax pretreatments alleviate chilling injury, enhance shelf life and preserve pomegranate fruit quality during cold storage. *Scientia Horticulturae*, *130*(4), pp.795-800.

Barman, K., Siddiqui, M.W., Patel, V.B. and Prasad, M., 2014. Nitric oxide reduces pericarp browning and preserves bioactive antioxidants in litchi. *Scientia Horticulturae*, *171*, pp.71-77.

Bot, P., Mun, B.G., Imran, Q.M., Hussain, A., Lee, S.U., Loake, G. and Yun, B.W., 2019. Differential expression of AtWAKL10 in response to nitric oxide suggests a putative role in biotic and abiotic stress responses. *Peer Journal*, *7*, pp 7383.

Cheema, A., Padmanabhan, P., Subramanian, J., Blom, T. and Paliyath, G., 2014. Improving quality of greenhouse tomato (*Solanum lycopersicum* L.) by pre-and postharvest applications of hexanal-containing formulations. *Postharvest biology and technology*, *95*, pp.13-19.

Chen, H.B. and Huang, X.M., 2012, December. Overview of litchi production in the world with specific reference to China. In *IV International Symposium on Lychee, Longan and OtherSapindaceae Fruits 1029* (pp. 25-33).

Dalal, N. and Siddiqui, S., 2019. Effect of chemical treatment, storage and packaging on physico-chemical properties of sunflower microgreens. *Int. J. Chem. Stud.*, *7*, pp.1046-1050.

Evans, E., Degner, R. and Morgan, K., 2004. Six Ways to Improve the Profitability of Lychee in South Florida. *EDIS*, *2004*(18).

Flores, F., Sánchez-Bel, P., Valdenegro, M., Romojaro, F., Martínez-Madrid, M., Egea, M., 2008. Effects of a pretreatment with nitric oxide on peach (Prunus persica L.) storage at room temperature. Eur. Food Res. Technol. 227, 1599–1611.

Gimenez, M., Olarte, C., Sanz, S., Lomas, C., Echavarri, J.F. and Ayala, F., 2003. Influence of packaging films on the sensory and microbiological evolution of minimally processed borage (Borrago officinalis). *Journal of food science*, *68*(3), pp.1051-1058.

Heremans K. (1995). High pressure effects on biomolecules. In: Ledward DA, Johnston DE, Earnshaw RG and Hasting APM (eds) High Pressure Processing of Foods. Leicestershire UK: Nottingham University Press, pp. 81–97

Jana, B.R., Das, B., Sharma, R. and Bhat, B.P., 2019. Performance of late season litchi cultivars grown in Jharkhand Province of India. *Journal*

of Applied and Natural Science, *11*(1), pp.12-16.

Joas, J., Caro, Y., Ducamp, M.N. and Reynes, M., 2005. Postharvest control of pericarp browning of litchi fruit (Litchi chinensis Sonn cv Kwaï Mi) by treatment with chitosan and organic acids: I. Effect of pH and pericarp dehydration. *Postharvest Biology and Technology*, *38*(2), pp.128-136.

Kayashima, T. and Katayama, T., 2002. Oxalic acid is available as a natural antioxidant in some systems. *Biochimica et Biophysica Acta (BBA)-General Subjects*, *1573*(1), pp.1-3.

Kesgin, M., Oksar, R.E. and Sen, F., 2018. Effects of shading and covering on 'Sultana Seedless' grape quality and storability.

Khan, A.S., Ahmad, N., Malik, A.U., and Amjad, M. 2012 Cold storage influences the postharvest pericarp browning and quality of litchi. *International Journal of Agriculture and Biology 14*(3): pp 389–394

Ku, V.V.V., Wills, R.B.H., Leshem, Y.Y., 2000. Use of nitric oxide to reduce postharvest water loss from horticultural produce. J. Hortic. Sci. Biotechnol. 75, 268–270

Kumar, M., Teotia, P., Prasad, R., Varma, A. and Kumar, V., 2017. The lychee fruit: Post harvest handling techniques. In *The lychee biotechnology* (pp. 193-211). Springer, Singapore.

Lichter, A., Dvir, O., Rot, I., Akerman, M., Regev, R., Wiesblum, A., Fallik, E., Zauberman, G. and Fuchs, Y., 2000. Hot water brushing: an alternative method to SO2 fumigation for color retention of litchi fruits. *Postharvest Biology and Technology*, *18*(3), pp.235-244.

Lin, H.T., 2002. Postharvest pericarp browning mechanism and postharvest handling of longan fruit. *PhD diss., Zhejiang University, Hangzhou, China*.

Manjunatha, G., Lokesh, V., Neelwarne, B., 2010. Nitric oxide in fruit ripening: trends and opportunities. Biotechnol. Adv. 28, 489–499.

Rajwana, I.A., Malik, A.U., Khan, A.S. and Anwar, R., 2008, August. Lychee industry in Pakistan: potential and prospects. In *III International Symposium on Longan, Lychee, and other Fruit Trees in Sapindaceae Family 863* (pp. 67-72).

Rajwanshi, R., Kumar, M. and Lal, B., 2017. Pre-and postharvest management practices for Litchi production in India. In *Lychee Disease Management* (pp. 45-66). Springer, Singapore.

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

Shukla, R.K., Painuly, D., Porval, A. and Shukla, A., 2012. Proximate analysis, nutritive value, total phenolic content and antioxidant activity of Litchi chinensis Sonn. *Nat Prod Indian J*, *8*, pp.361-9.

Singh, S.P., Singh, Z., Swinny, E.E., 2009. Post-harvest nitric oxide fumigation delays fruit ripening and alleviates chilling injury during cold storage ofJapanese plums (Prunus salicina Lindell). Postharvest Biol. Technol. 53, 101–108.

Sivakumar, D., Regnier, T., Demoz, B. and Korsten, L., 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), pp.32-38.

Talukder, F.U., Rahman, M.S. and kamrul Hassan, M., 2020. Effects of Polypropylene Bag on Storage Properties of Litchi (Litchi Chinensis Sonn.). *Agricultural Science*, *2*(1), pp.p144-p144.

Tanada-Palmu, P.S. and Grosso, C.R., 2005. Effect of edible wheat gluten-based films and coatings on refrigerated strawberry (Fragaria ananassa) quality. *Postharvest biology and technology*, *36*(2), pp.199-208.

Uthaibutra, J., 2015. Effect of fruit dipping in sodium hypochlorite and oxalic acid then coating in bees-carnauba mixed wax on peel browning and decay of Vietnamese longan fruit.

Zaharah, S.S., Singh, Z., 2011. Postharvest nitric oxide fumigation alleviates chilling injury, delays fruit ripening and maintains quality in cold stored 'Kensington Pride' mango. Postharvest Biol. Technol. 60, 202–210.

Zhu, S., Sun, L., Zhou, J., 2009. Effects of nitric oxide fumigation on phenolic metabolism of postharvest Chinese winter jujube (Zizyphus jujuba Mill. cv. Dongzao) in relation to fruit quality. LWT: Food Sci. Technol. 42, 1009–1014.