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# Studies on Zeolite-LDPE Composite Bags to Extend the Shelf Life of Acid Lime Fruits Stored at Ambient Conditions

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**ABSTRACT**

The present investigation consisting of different treatments *viz* $T_1$-Zeolite-LDPE composite bag, $T_2$-Silver-zeolite-LDPE composite bag, $T_3$-Chlorine-zeolite-LDPE composite bag, $T_4$- Zeolite-LDPE composite bag + CFB, $T_5$-Silver-zeolite-LDPE composite bag + CFB, $T_6$-Chlorine-zeolite-LDPE composite bag + CFB, $T_7$-Only CFB, $T_8$ – Common polybag and $T_9$ – Control was carried out in Department of Post-harvest Technology, College of Horticulture, Bagalkot during the year 2018-19. The experiment was laid out in a completely randomized design with three replications. The main objective was to find out the effective packaging material to extend the shelf life of acid lime fruits. Various physico-chemical quality traits were recorded at regular interval during storage of fruits. The acid lime fruits packed in $T_6$ showed maximum titratable acidity (7.33 %), juice percentage (50.01 %), Texture (35.27 N) and minimum PLW (17.04 %), fruit decay (20.74 %),total soluble solids (7.20 ºB), TSS/Acid ratio (0.98) and highest sensory scores among the treatments during storage of 12 days.

## Introduction

Citrus (*Citrus* sp.) is the third most important fruit of India after mango and banana, has a prominent place among the popularly grown tropical and subtropical fruits in India. One of the most important Citrus species grown is acid lime (*Citrus aurantifolia* Swingle) which occupies 22.3 per cent of total area under this crop. In India, it is known to be grown in an area of 259 (000 Ha) with a production of 2789 (000MT) and productivity of 10.05 MT/Ha (NHB, 2017).

Citrus fruits are non-climacteric, with persistently low respiration and ethylene production rates, do not undergo any major softening or compositional changes after harvest therefore, can normally be stored for long periods (Kader, 2002). However, two major problems limit facing the long-term storage capability of citrus fruit: the first is pathological and physiological breakdown leading to decay and rind disorders; the second is weight loss especially in acid lime fruits (Purvis, 1983). In acid lime postharvest decay is the major factor limiting the extension of storage life and cause quality deterioration rendering fresh fruit, unsuitable for consumption. Thus, retention of quality in fruits for a longer period is one of the most important aspects of post harvest handling and storage. In places where refrigeration and storage facilities are not available, packaging plays an important role to increasing storage life of fresh fruits.

Zeolite is a large and diverse class of volcanic aluminosilicate crystalline material which has many useful applications (Khosravi *et al.*, 2015). The use of zeolite as an adsorbent has started in 1930s followed by Milton, who used zeolite for air purification (Kamarudin, 2006). Zeolite is a nanoporous crystalline alumina silicate having trihedral and tetrahedral structure. It contains large vacant spaces or cages in its structure that provide space for adsorption of cations or large molecules such as water, ammonia and ethylene (Khosravi*et al.*, 2015).

## Materials and Methods

The present investigation was conducted at Department of Post-harvest Technology, College of Horticulture, Bagalkot, Karnataka during the year 2018-19. The experiment comprised of eight treatments *viz.*,$T_1$-Zeolite-LDPE composite bag, $T_2$-Silver-zeolite-LDPE composite bag, $T_3$-Chlorine-zeolite-LDPE composite bag, $T_4$- Zeolite-LDPE composite bag + CFB, $T_5$-Silver-zeolite-LDPE composite bag + CFB, $T_6$-Chlorine-zeolite-LDPE composite bag + CFB,$T_7$-Only CFB, $T_8$ – Common polybag and $T_9$ – Control (without any package) with three replications. The acid lime fruits procured from a farmer's field located at sokanadagi village in Bagalkot district of Karnataka were used in the experiment. Well developed, good looking fruits with uniformity in size and free from pest and disease attack were harvested at right stage of maturity and brought to the laboratory. Then the fruits were precooled about half an hour in cool chamber then washed with chlorine water of 50 ppm concentration. The fruits were air dried and packed in different packages then kept for storage.

Observations were recorded at 4, 8, 10 and 12 days interval. Then randomly select two to three fruits for analysis. The titratable acidity of the juice was determined as per the method advocated by A.O.A.C (1975) by titrating five ml of juice was diluted to 100 ml by adding distilled water. From this, 10 ml of aliquot was taken in pomegranate and titrated against standard sodium hydroxide solution (0.1N), using phenolphthalein indicator. The appearance of light pink colour was recorded as end point. The acidity of juice was expressed in percentage as citric acid (Ranganna, 1986). PLW was calculated by the difference between initial and subsequent weights and it was expressed as percentage. To determine juice percentage of fruit, the juice was extracted from whole fruit by using lime squeezer. The extracted juice was weighed by using an electronic weighing balance and the juice content was calculated by using formula*i.e.*, weight of juice extracted to the total weight of the fruit and the same juice was used to know total soluble solids by using digital refractometer. Texture of the fruit was determined by using texture analyser (Stable Micro Systems). Fruit decay was determined by number of spoiled fruits at each interval of observation and percentage was calculated on the basis of total number of fruits stored in each treatment.

Sensory evaluation during storage of lime fruits was carried out by 9 point hedonic scale

(1 = Dislike extremely, 2 = Dislike very much, 3 = Dislike moderately, 4 = Dislike slightly, 5 = Neither like or dislike, 6 = Like slightly, 7 = Like moderately, 8 = Like very much, 9 = Like extremely). Sensory parameters considered in evaluation are colour and appearance of fruit, firmness, juice flavour and overall acceptability.

## Results and Discussion

### Physiological loss in weight (%)

Irrespective of treatments there was increase in PLW with progress in storage period(Table 1). The PLW was found to be significantly affected with different treatments. The PLW was found to be highest in $T_9$ (34.78 %) *i.e.*, fruits without packaging (control) and lowest in $T_6$ (17.04%) *i.e.,* Chlorine-zeolite-LDPE composite bag + CFB followed by $T_5$ (20.58%) *i.e.,* Silver-zeolite-LDPE composite bag + CFB at the end of storage. The increase in PLW may be due to higher respiration rate also resulted in higher transpiration of water from the fruit surface which led to increase in percentage of weight loss (Sabir *et al*., 2004).The lowest PLW in case of treatment $T_6$ even after 12days of storage may be because of LDPE Composite bags + CFB, which might have reduced the transpiration and respiration due to modified atmosphere created in CFB which might also acts as a physical barrier for transpiration. Further, it may also be as a result of less amount of water transpired from the fruits.

### Total soluble solids (°Brix)

The data reported that there was significant difference between the treatments in relation to TSS of acid lime fruits during different storage intervals (Table 1). TSS content of lime fruits increased progressively with an increase in storage period from 4$^{th}$ day (7.18 °B) to 12$^{th}$ day (7.41 °B) of storage. The lowest TSS on 12 DAS was observed in $T_6$-7.20 °B *i.e.,* fruits packed in Chlorine-zeolite - LDPE composite bag + CFB, which was on par with $T_5$ (7.26 °B) *i.e.,* fruits packed in Silver-zeolite-LDPE composite bag + CFB. This might be attributed to the sole reason that respiration causes the starch to hydrolysis and therefore increases the Brix. Zeolite by adsorbing oxygen, carbon dioxide and ethylene can prevent increase in Brix value. Further it may also be due to CFB packed fruits retard ripening and senescence processes and simultaneously reduced the conversion of starch into sugars. Where as highest TSS was noticed in control ($T_9$-7.61 °B) which was on par with$T_7$ (7.57 °B) which might be due to conversion of starch and other polysaccharides into soluble forms of sugar. In general, the increase in TSS during the storage period may be due to the numerous catabolic processes taking place in the fruits, preparing it for senescence. There is no significant difference between $T_1$ (7.46), $T_2$ (7.43) and $T_8$ (7.43) after 12 days of storage. However $T_3$ and $T_4$ were on par with each other but significant over control.

### Titratable acidity (%)

From the Table 2 it is evident that the titratable acidity of acid lime fruits showed decreasing trend with the progressing storage period. The maximum titratable acidity was observed in $T_6$ (7.33 %) which was on par with $T_5$ (7.12 %). The maintenance of acidity in these treatments might be due the most important features of zeolites as they are effective in adsorbing gases such as oxygen, carbon dioxide and ethylene, and water vapours due to presence of pores. Zeolite causes the adsorption of these gases and thus reducing the breathing and advances of metabolism in fruits (Khosravi *et al.,* 2015). Minimum acidity was noticed in control *i.e.,* $T_9$ (6.07 %) followed by $T_7$ (6.13 %) at the end of storage. This is due to low availability of oxygen in packaged fruits, the organic acid involved in the respiratory process, is not utilized as substrate. These findings are in general agreement with the results of Tarkase and Desai (1989) in oranges and Dhilon *et al*. (1977) in kinnow mandarins.

### TSS/Acid Ratio

The effect of different packaging materials on TSS/Acid ratio of acid lime fruits under ambient storage condition is represented in Table 2.

The TSS/acid ratio increased with the advancement of storage period with mean value from $4^{th}$ to $12^{th}$ day (0.99 to 1.14) of storage in ambient. The minimum TSS/acid ratio was noticed after 12 days of storage in $T_6$ (0.98) which was on par with $T_5$ (1.02) *i.e.,* Silver-zeolite-LDPE composite bag + CFB, $T_4$ (1.06) and $T_3$ (1.09) *i.e.,* Chlorine containing LDPE composite bag. This could be due to the fact that Zeolite causes the adsorption of these gases (oxygen, carbon dioxide and ethylene, and water vapours) and thus reduces the breathing and advances of metabolism in fruits and can prevent increase in Brix value (Khosravi *et al.,* 2015). Further it may also be due to CFB packed fruits retard ripening and senescence processes and simultaneously reduced the conversion of starch into sugars and maximum TSS/acid ratio was observed in $T_9$ (1.25) *i.e.,* control which was followed by $T_7$ (1.24) , $T_1$ (1.20), $T_2$ (1.20) and $T_8$ (1.17) being on par with each other. Which may be linked to conversion of starch and other polysaccharides into soluble forms of sugar. Wills *et al.* (1989) have also reported that starch gets hydrolyzed into mono and disaccharides, which in turn may lead to an increase in TSS.

### Juice percentage (%)

The data revealed that there was significant difference between the treatments when compared to control in relation to juice per cent of acid lime fruits(Table 3).The data on the juice per cent of acid lime fruits showed a decreasing trend with the advancement of storage period. At the end of storage maximum fruit juice per cent was observed in $T_6$ (50.01 %) followed by $T_5$(48.23 %). This could be ascribed to the minimum loss of water from the fruit surface, further the elevated carbon dioxide levels inhibit the compositional changes and softening of tissues (Kubo *et al.,* 1989). Previous reports of highest juice content were also found in citrus fruits (Bullar, 1988). Further, it may also be due to the reason that packaging material CFB provides appropriate environment, ventilation and maintained high humidity inside the pack by accumulation of $CO_2$ and depletion of $O_2$. Where as minimum juice content was observed in control *i.e.,* $T_9$ (36.28 %). This is probably due to the absence of altered atmosphere and higher loss of moisture, leading to weight loss and hence the higher compositional changes in the fruit leading to the low juice percentage.

### Fruit decay (%)

Fruit decay started to be observed (Table 3) on $4^{th}$ day after storage itself in case of treatments $T_7$ (9.52 %), $T_8$ (4.76 %) and $T_9$(17.86 %). At the end 12 days of storage lowest fruit decay was observed in treatment $T_6$(20.74 %) followed by $T_5$(43.45 %). This may be because of the incorporation of chlorine into packaging which could effectively inhibit the growth of fruit microorganisms. The antibacterial mechanism of silver and zeolite composite bags can be related to membrane damage caused by free radicals derived from the surface of silver and zeolite (Zhang *et al.,* 2018). Whereas control fruits showed 100 per cent fruit decay. The highest decay may be ascribed to skin injury or cracking caused degradation of cell wall as well as it increases the respiration rate and the micro climate inside the package which results in decaying and rotting of fruits and consequently occurrence of the pathogen.

## Texture (N)

Table 4 representing data on texture of acid lime fruits as affected by different packaging materials under ambient storage conditions.

Texture of fruit progressively declined during storage of lime fruits in all treatments with mean value from 4$^{th}$ day to 12$^{th}$ day (44.38 N to 26.24 N) of storage. The data revealed that there was significant difference between the treatments in relation to texture of acid lime fruits compared to control and $T_7$during different storage intervals. Fruits packed in $T_6$ (35.27 N) *i.e.*, Chlorine-zeolite -LDPE composite bag + CFB maintained higher fruit firmness after 12DAS followed by $T_5$(34.15 N),$T_4$ (30.51 N). This might be because the water vapour permeability of mixed membranes (chlorine or zeolite) was higher than that of other membranes and also chlorine has certain antibacterial properties as well. Where as minimum firmness was recorded in control fruits ($T_9$-16.07 N) which was on par with $T_7$(16.24 N). The minimum firmness during storage could be due to more degradation of soluble pectin by higher activity of endopolygalacturonase, PE and PME enzyme in fruits. Further it may also be due to low-permeability of packaging as in case of $T_7$ which could increase the relative humidity inside the package to accelerate the softening of the acid lime. Other treatments ($T_1$, $T_2$, $T_3$, and $T_8$) showed statistically significant and intermediate results compared to the control.

## Sensory evaluation

The data on organoleptic evaluation with respect to colour and appearance, firmness, juice flavour and overall acceptability of acid lime fruits as influenced by storage temperature and different packaging materials are presented in Table 5 to 6.

## Colour and appearance

The sensory scores of colour and appearance of stored lime fruits are presented in Table 5. The results indicated that, there was a significant difference among all the treatments. The sensory score of colour and appearance decreased with storage period. Among the treatments at the end of storage, highest score was recorded in $T_6$(6.00 at 12 DAS) followed by $T_5$ (5.03 ) as shown in plate 1 and plate 2. This is due to packaging materials form a cover over the fruits leading to retention colour pigments and reduction in oxygen concentration.

As a result, the respiration in fruits may slow down due to which the degeneration of colour in packed fruits is reduced. Whereas lowest score was observed in control ($T_9$), only CFB boxes ($T_7$), common polybags ($T_8$), $T_1$ and $T_2$ at the end of storage. This may be due to increase in shrinkage at the end of storage. The present findings are supported by the result obtained by the Siddiqui *et al*. (1997) and Mandhyan (1999).

## Firmness

The sensory scores of firmness of acid lime fruits as influenced by the different packaging material is presented Table 5. The results from the table revealed that, the score for firmness decreased as the storage period progressed. However, there was no significant difference observed among the treatments at 4 days of storage. At the end of storage highest score for firmness was given to treatment $T_6$ (6.08 at 12 DAS) followed by $T_5$(5.00 at 12 DAS) whereas lowest score was observed in control and only CFB box (1.00).

**Table.1** Effect of zeolite based packages on physiological loss in weight (PLW) and total soluble solids (TSS) of acid lime fruits stored at ambient condition (33±1 ºC and 37±1% RH)

| Treatments | Physiological loss in weight (%) | | | | | Total soluble solids (º Brix) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after storage | | | | | Days after storage | | | | |
| | 4 | 8 | 10 | 12 | Mean | 4 | 8 | 10 | 12 | Mean |
| $T_1$ | 10.20 | 17.18 | 22.21 | 25.81 | **18.85** | 7.22 | 7.31 | 7.37 | 7.46 | **7.26** |
| $T_2$ | 9.99 | 16.67 | 22.02 | 25.20 | **18.47** | 7.22 | 7.30 | 7.37 | 7.43 | **7.25** |
| $T_3$ | 9.44 | 16.28 | 20.47 | 22.67 | **17.21** | 7.19 | 7.27 | 7.35 | 7.37 | **7.23** |
| $T_4$ | 8.82 | 12.80 | 16.93 | 21.77 | **15.08** | 7.12 | 7.21 | 7.26 | 7.30 | **7.17** |
| $T_5$ | 7.56 | 11.99 | 16.60 | 20.58 | **14.18** | 7.07 | 7.17 | 7.21 | 7.25 | **7.13** |
| $T_6$ | 5.18 | 9.39 | 12.61 | 17.04 | **11.05** | 6.99 | 7.10 | 7.13 | 7.20 | **7.07** |
| $T_7$ | 13.06 | 20.01 | 25.36 | 32.23 | **22.67** | 7.28 | 7.35 | 7.44 | 7.57 | **7.31** |
| $T_8$ | 10.23 | 17.55 | 23.40 | 26.96 | **19.53** | 7.21 | 7.30 | 7.38 | 7.43 | **7.25** |
| $T_9$ | 13.70 | 22.06 | 26.64 | 34.78 | **24.30** | 7.31 | 7.39 | 7.47 | 7.61 | **7.34** |
| **Mean** | **9.80** | **15.99** | **20.69** | **25.23** | | **7.18** | **7.27** | **7.33** | **7.41** | |
| **S.Em±** | 0.56 | 0.78 | 0.86 | 0.92 | | 0.02 | 0.02 | 0.02 | 0.02 | |
| **CD at 1%** | 2.29 | 3.18 | 3.50 | 3.74 | | 0.08 | 0.08 | 0.07 | 0.07 | |
| **Initial value: NIL** | | | | | | Initial value: 6.92 º Brix | | | | |

**Table.2** Effect of zeolite based packages on titratable acidity and TSS/Acid ratio of acid lime fruits stored at ambient condition (33±1 ºC and 37±1% RH)

| Treatments | Titratable acidity (% of citric acid) | | | | | TSS/ACID Ratio | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after storage | | | | | Days after storage | | | | |
| | 4 | 8 | 10 | 12 | Mean | 4 | 8 | 10 | 12 | Mean |
| $T_1$ | 7.11 | 6.68 | 6.43 | 6.22 | **6.86** | 1.02 | 1.09 | 1.15 | 1.20 | **1.07** |
| $T_2$ | 7.14 | 6.77 | 6.53 | 6.18 | **6.89** | 1.01 | 1.08 | 1.13 | 1.20 | **1.06** |
| $T_3$ | 7.22 | 7.06 | 6.92 | 6.65 | **7.14** | 1.00 | 1.03 | 1.06 | 1.09 | **1.02** |
| $T_4$ | 7.53 | 7.22 | 7.06 | 6.91 | **7.31** | 0.95 | 1.00 | 1.03 | 1.06 | **0.98** |
| $T_5$ | 7.57 | 7.38 | 7.26 | 7.12 | **7.43** | 0.93 | 0.97 | 0.99 | 1.02 | **0.96** |
| $T_6$ | 7.76 | 7.58 | 7.44 | 7.33 | **7.59** | 0.90 | 0.94 | 0.96 | 0.98 | **0.93** |
| $T_7$ | 6.93 | 6.50 | 6.32 | 6.13 | **6.74** | 1.05 | 1.13 | 1.18 | 1.24 | **1.10** |
| $T_8$ | 7.44 | 6.63 | 6.55 | 6.37 | **6.97** | 0.97 | 1.10 | 1.13 | 1.17 | **1.05** |
| $T_9$ | 6.83 | 6.35 | 6.28 | 6.07 | **6.67** | 1.07 | 1.16 | 1.19 | 1.25 | **1.11** |
| **Mean** | **7.28** | **6.91** | **6.75** | **6.54** | | **0.99** | **1.06** | **1.09** | **1.14** | |
| **S.Em±** | 0.15 | 0.13 | 0.11 | 0.12 | | 0.02 | 0.02 | 0.02 | 0.02 | |
| **CD at 1%** | 0.60 | 0.51 | 0.44 | 0.48 | | 0.09 | 0.09 | 0.08 | 0.1 | |
| **Initial value: 7.84 %** | | | | | | Initial value: 0.88 | | | | |

**Table.3** Effect of zeolite based packages on juice percentage and fruit decay of acid lime fruits stored at ambient condition (33±1 ºC and 37±1% RH)

| Treatments | Juice percentage | | | | | Fruit decay (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after storage | | | | | Days after storage | | | | |
| | **4** | **8** | **10** | **12** | **Mean** | 4 | 8 | 10 | 12 | **Mean** |
| **$T_1$** | 53.98 | 46.74 | 43.69 | 39.45 | **48.04** | 0.00 | 43.59 | 79.06 | 100.00 | **55.66** |
| **$T_2$** | 54.56 | 47.60 | 44.53 | 40.89 | **48.78** | 0.00 | 35.90 | 56.98 | 100.00 | **48.22** |
| **$T_3$** | 54.89 | 48.77 | 45.30 | 42.82 | **49.62** | 0.00 | 20.51 | 34.02 | 94.67 | **37.30** |
| **$T_4$** | 55.14 | 50.89 | 48.02 | 44.88 | **51.05** | 0.00 | 12.82 | 25.87 | 73.26 | **27.99** |
| **$T_5$** | 55.41 | 51.53 | 49.56 | 48.23 | **52.21** | 0.00 | 8.97 | 20.06 | 43.45 | **18.12** |
| **$T_6$** | 55.96 | 53.70 | 51.37 | 50.01 | **53.48** | 0.00 | 1.28 | 9.90 | 20.74 | **7.98** |
| **$T_7$** | 51.16 | 46.69 | 41.78 | 38.07 | **46.81** | 9.52 | 56.53 | 83.20 | 100.00 | **62.31** |
| **$T_8$** | 53.25 | 48.15 | 45.29 | 37.37 | **48.39** | 4.76 | 21.67 | 46.30 | 100.00 | **43.18** |
| **$T_9$** | 49.45 | 44.41 | 39.43 | 36.28 | **45.33** | 17.86 | 73.12 | 100.00 | 100.00 | **72.75** |
| **Mean** | **53.76** | **48.72** | **45.44** | **42.00** | | **3.57** | **30.49** | **50.60** | **81.35** | |
| **S.Em±** | 1.24 | 2.06 | 1.66 | 0.76 | | 0.89 | 1.62 | 2.48 | 0.68 | |
| **CD at 1%** | NS | NS | 6.75 | 3.07 | | 3.61 | 6.59 | 10.08 | 2.75 | |
| **Initial value: 56.33 %** | | | | | | Initial value: NIL | | | | |

**Table.4** Effect of zeolite based packages on texture of acid lime fruits stored at ambient condition (33±1 ºC and 37±1%RH)

| Treatments | Texture/Firmness (N) | | | | |
|---|---|---|---|---|---|
| | Days after storage | | | | |
| | **4** | **8** | **10** | **12** | **Mean** |
| **$T_1$** | 45.43 | 32.99 | 27.59 | 25.96 | **36.22** |
| **$T_2$** | 46.04 | 33.20 | 28.44 | 26.77 | **36.71** |
| **$T_3$** | 46.20 | 34.22 | 28.42 | 27.81 | **37.15** |
| **$T_4$** | 46.91 | 42.76 | 31.82 | 30.51 | **40.22** |
| **$T_5$** | 47.81 | 43.38 | 35.36 | 34.15 | **41.96** |
| **$T_6$** | 48.41 | 45.00 | 36.52 | 35.27 | **42.86** |
| **$T_7$** | 37.92 | 18.97 | 17.27 | 16.24 | **27.90** |
| **$T_8$** | 44.75 | 32.07 | 25.13 | 23.40 | **34.89** |
| **$T_9$** | 35.97 | 17.20 | 16.56 | 16.07 | **26.98** |
| **Mean** | **44.38** | **33.31** | **27.46** | **26.24** | |
| **S.Em±** | 0.23 | 0.12 | 0.24 | 0.31 | |
| **CD at 1%** | 0.92 | 0.83 | 1.66 | 1.25 | |
| **Initial value: 49.10 N** | | | | | |

**Table.5** Effect of zeolite based packages on colour and appearance and firmness of acid lime fruits stored at ambient condition(33±1 ºC and 37±1% RH)

| Treatments | Colour and appearance | | | | | Firmness | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after storage | | | | | Days after storage | | | | |
| | 4 | 8 | 10 | 12 | Mean | 4 | 8 | 10 | 12 | Mean |
| $T_1$ | 8.00 | 4.00 | 1.00 | 1.00 | **4.60** | 9.00 | 4.00 | 2.00 | 1.00 | **5.00** |
| $T_2$ | 8.00 | 4.00 | 1.00 | 1.00 | **4.60** | 9.00 | 4.00 | 2.00 | 1.00 | **5.00** |
| $T_3$ | 8.73 | 6.17 | 2.67 | 2.00 | **5.71** | 9.00 | 6.93 | 2.33 | 1.00 | **5.65** |
| $T_4$ | 8.17 | 7.07 | 5.83 | 5.00 | **7.01** | 9.00 | 7.07 | 5.97 | 4.10 | **7.03** |
| $T_5$ | 8.90 | 7.33 | 5.99 | 5.03 | **7.25** | 9.00 | 7.17 | 6.17 | 5.00 | **7.27** |
| $T_6$ | 9.00 | 8.08 | 7.04 | 6.00 | **7.82** | 9.00 | 8.00 | 7.20 | 6.08 | **7.84** |
| $T_7$ | 7.00 | 2.00 | 1.00 | 1.00 | **4.00** | 9.00 | 1.00 | 1.00 | 1.00 | **4.20** |
| $T_8$ | 8.00 | 4.00 | 1.67 | 1.00 | **4.73** | 9.00 | 3.13 | 1.73 | 1.00 | **4.77** |
| $T_9$ | 7.00 | 1.00 | 1.00 | 1.00 | **3.80** | 9.00 | 1.00 | 1.00 | 1.00 | **4.20** |
| **Mean** | **8.09** | **4.85** | **3.02** | **2.56** | | **9.00** | **4.70** | **3.27** | **2.34** | |
| **S.Em±** | 0.11 | 0.08 | 0.17 | 0.01 | | NS | 0.09 | 0.18 | 0.03 | |
| **CD at 1%** | 0.45 | 0.34 | 0.69 | 0.04 | | NS | 0.36 | 0.73 | 0.13 | |
| **Initial value: 9.00** | | | | | | Initial value:9.00 | | | | |

**Table.22** Effect of zeolite based packages on juice flavour and over all acceptability ofacid lime fruits stored at ambient condition (33±1ºC and 37±1% RH)

| Treatments | Juice flavor | | | | | Over all acceptability | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Days after storage | | | | | Days after storage | | | | |
| | 4 | 8 | 10 | 12 | Mean | 4 | 8 | 10 | 12 | Mean |
| $T_1$ | 9.00 | 5.00 | 4.00 | 2.17 | **5.83** | 8.67 | 4.33 | 2.33 | 1.39 | **5.14** |
| $T_2$ | 9.00 | 5.00 | 4.00 | 3.00 | **6.00** | 8.67 | 4.33 | 2.33 | 1.67 | **5.20** |
| $T_3$ | 9.00 | 7.00 | 6.10 | 4.07 | **7.03** | 8.91 | 6.70 | 3.70 | 2.36 | **6.13** |
| $T_4$ | 9.00 | 7.81 | 7.00 | 5.21 | **7.60** | 8.72 | 7.31 | 6.27 | 4.77 | **7.21** |
| $T_5$ | 9.00 | 7.83 | 7.07 | 6.33 | **7.85** | 8.97 | 7.44 | 6.41 | 5.46 | **7.46** |
| $T_6$ | 9.00 | 8.13 | 7.99 | 7.86 | **8.40** | 9.00 | 8.07 | 7.41 | 6.62 | **8.02** |
| $T_7$ | 9.00 | 4.00 | 3.00 | 2.00 | **5.40** | 8.33 | 2.33 | 1.67 | 1.33 | **4.53** |
| $T_8$ | 9.00 | 3.97 | 2.93 | 2.00 | **5.38** | 8.67 | 3.70 | 2.11 | 1.33 | **4.96** |
| $T_9$ | 9.00 | 3.00 | 1.00 | 1.00 | **4.60** | 8.33 | 1.67 | 1.00 | 1.00 | **4.20** |
| **Mean** | **9.00** | **5.75** | **4.79** | **3.74** | | **8.70** | **5.10** | **3.69** | **2.88** | |
| **S.Em±** | 0.00 | 0.09 | 0.04 | 0.12 | | 0.04 | 0.04 | 0.08 | 0.04 | |
| **CD at 1%** | NS | 0.36 | 0.19 | 0.48 | | 0.15 | 0.15 | 0.34 | 0.16 | |
| **Initial value: 9.00** | | | | | | Initial value: 9.00 | | | | |

The higher retention of firmness in Chlorine-zeolite -LDPE composite bag + CFB box over the control may be due to the fact that packaging prevents the direct evapo-transpiration and lowered the physiological loss in weight and also helped to maintain turgidity, higher firmness and freshness and retained the respiratory substrates (carbohydrates, proteins, and fats) from getting broken down into simple end products during storage. The present findings are supported by Sonkar and Ladaniya (1999) and Ladaniya and Singh, (2001).

### Juice flavour

The juice flavour of lime fruits decreased in lime fruits as storage period progressed (Table 7). There was no significant difference observed among the treatments at 4 days of storage. But at the end of storage in both ambient and refrigerated storage the highest score for juice flavour was given to treatment T6 (7.86 at 12 DAS) followed by T5 (6.33 at 12 DAS) and lowest score was recorded in control fruits (1.00). The reason for lower flavour value was due to increase in ripening at the end of storage. Our results are in corollary with those of Bisen*et al*. (2012) who found that decrease in flavour of lime fruits. The present findings are supported by Sonkar and Ladaniya (1999).

### Overall acceptability

The data on overall acceptability of acid lime fruits is presented in Table 8. The overall acceptability of lime fruits decreased with the increase in storage period. The data revealed that there was significant difference among treatments compared to control. After 12 days of storage highest overall acceptability score of acid lime fruits was accorded to $T_6$ (6.62) followed by $T_5$ (5.46). However, lowest score was given to control fruits (1.00).

On the basis of results obtained it can be recommended that Chlorine zeolite-LDPE composite bags with CFB boxes were found to be economically viable to extend shelf-life of acid lime fruits under ambient storage conditions. It can be concluded that acid lime fruits packed in chlorine-zeolite-LDPE composite bag + CFB ($T_6$) were able to extend shelf life by 7 days more in compare to control (5 days)with maintaining all sensory characters at the end of storage.

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