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Effect of chlorine and silver synergized zeolite-LDPE composite bags on biochemical properties of acid lime stored in refrigerated condition

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Abstract
The potential 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 on storage behaviour of acid lime fruits 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 in refrigerated condition. Fruits placed in Chlorine-zeolite-LDPE composite bag + CFB (T_6) showed maximum titratable acidity (7.01%), juice percentage (51.24%) and minimum PLW (14.21%), fruit decay (24.11%) and highest sensory scores among the treatments during storage of 80 days.

Keywords: Acid lime, Zeolite, LDPE, fruit decay, organoleptic quality

Introduction
Citrus fruit 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) [5]. 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) [11]. 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) [7]. The use of zeolite as an adsorbent has started in 1930s followed by Milton, who used zeolite for air purification (Kamarudin, 2006) [6]. 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) [7].

Material 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 every 10 days interval in refrigerated storage and 4, 8, 10 and 12 days interval in ambient storage. Then randomly select single fruit 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) [12]. 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. 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 in (Table 1). The PLW was found to be significantly affected with different treatments. The PLW was found to be highest in T_9 (36.96%) *i.e.*, fruits without packaging (control) and lowest in T_6 (14.21%) *i.e.*, Chlorine-zeolite-LDPE composite bag + CFB followed by T_5 (18.32%) *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) [13]. The lowest PLW in case of treatment T_6 even after 80 DAS in refrigerated condition 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.

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 in both ambient and refrigerated storage. The maximum titratable acidity was observed in T_6 (7.01%) which was on par with T_5 (6.88%) 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) [7]. Minimum acidity was noticed in control (6.17%) followed by T_7 (6.33%) 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) [16] in oranges and Dhilon *et al*. (1977) [4] in kinnow mandarins.

Table 1: Effect of zeolite based packages on physiological loss in weight (PLW %) of acid lime fruits stored at refrigerated conditions (10º C and 85-90% RH)

Treatments	Refrigerated storage							
	Days of storage							
	10	20	30	40	50	60	70	80
T_1	5.16	8.57	9.4	13.73	17.94	22.26	25.63	29.01
T_2	5.27	7.9	8.88	12.29	16.57	20.86	23.49	26.9
T_3	5.13	7.7	9.41	11.97	16.22	20.48	23.04	25.61
T_4	2.66	5.32	6.25	8.91	13.3	16.79	20.29	22.95
T_5	0.73	3.13	5.52	7.17	9.56	11.95	15.93	18.32
T_6	0.5	0.74	3.00	4.51	6.76	8.6	11.95	14.21
T_7	4.94	9.87	14.05	17.47	22.21	26.19	30.17	34.16
T_8	4.86	7.29	9.02	12.14	15.27	18.53	23.39	28.04
T_9	5.85	10.1	14.35	18.60	22.77	26.94	31.11	36.96
Mean	3.9	6.73	8.87	11.86	15.62	19.18	22.78	26.24
S.Em±	0.25	0.67	1.34	1.55	1.07	0.85	0.86	0.88
CD at 1%	1.02	2.73	5.46	6.29	4.37	3.48	3.51	3.58

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 in refrigerated storage conditions (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 (51.24%) followed by T_5 (48.76%). 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) [8]. Previous reports of highest juice content were also found in citrus fruits (Bullar, 1988) [3]. 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 (38.57%). 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.

Table 2: Effect of zeolite based packages on titratable acidity (% of citric acid) of acid lime fruits stored at refrigerated conditions (10º C and 85-90% RH)

Treatments	Refrigerated storage							
	Days of storage							
	10	20	30	40	50	60	70	80
T_1	7.37	7.30	7.24	7.17	7.08	6.90	6.80	6.52
T_2	7.47	7.37	7.30	7.20	7.13	6.96	6.84	6.57
T_3	7.54	7.41	7.33	7.23	7.15	7.02	6.89	6.66
T_4	7.57	7.47	7.42	7.33	7.24	7.06	6.99	6.78
T_5	7.6	7.53	7.48	7.39	7.31	7.14	7.04	6.88
T_6	7.66	7.63	7.55	7.47	7.39	7.28	7.12	7.01
T_7	7.31	7.20	7.12	7.02	6.91	6.73	6.60	6.33
T_8	7.37	7.30	7.2	7.12	7.04	6.88	6.78	6.53
T_9	7.30	7.12	7.06	6.93	6.82	6.62	6.51	6.17
Mean	7.47	7.37	7.3	7.21	7.12	6.95	6.84	6.61
S.Em±	0.13	0.13	0.13	0.13	0.13	0.10	0.08	0.05
CD at 1%	NS	NS	NS	NS	NS	0.40	0.33	0.21

Initial value: 7.70%

Fruit decay (%)

Fruit decay started on 40th day after storage in T_7 (3.10%) and T_9 (6.36%). At the end of storage lowest fruit decay was observed in treatment T_6 (24.11%) followed by T_5 (43.47%). 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) [17]. 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.

Table 3: Effect of zeolite based packages on juice percentage of acid lime fruits stored at refrigerated conditions (10º C and 85-90% RH)

Treatments	Refrigerated storage							
	Days of storage							
	10	20	30	40	50	60	70	80
T_1	58.45	57.72	56.76	55.3	53.9	52.22	47.14	45.25
T_2	58.49	57.95	56.94	55.7	54.61	52.86	47.93	45.62
T_3	58.33	57.91	57.24	56.17	55.46	53.9	48.86	46.48
T_4	58.69	58.25	57.53	56.67	55.65	54.41	50.09	47.66
T_5	58.7	58.43	57.84	57.13	56.18	54.84	51.72	48.76
T_6	58.74	58.7	58.18	57.62	56.88	56	53.42	51.24
T_7	58.4	57.53	56.33	54.86	52.93	51.15	45.7	41.49
T_8	58.53	57.71	56.61	55.15	53.75	51.98	46.99	43.78
T_9	58.27	57.39	55.83	54.02	49.82	47.83	43.33	38.57
Mean	58.51	57.95	57.03	55.85	54.47	52.8	48.35	45.43
S.Em±	0.78	0.84	0.78	0.95	1.05	1.26	0.47	0.57
CD at 1%	3.19	3.44	3.18	3.87	4.28	5.14	1.92	2.3

Initial value: 58.75%

Table 4: Effect of zeolite based packages on fruit decay (%) of acid lime fruits stored at refrigerated conditions (10º C and 85-90% RH)

Treatments	Refrigerated storage				
	Days after storage				
	40	50	60	70	80
T_1	0.00	5.5	21.57	48.48	85.19
T_2	0.00	0.00	15.14	37.13	83.17
T_3	0.00	0.00	10	25.7	69.44
T_4	0.00	0.00	3.94	19.17	47.23
T_5	0.00	0.00	0.00	12.78	43.47
T_6	0.00	0.00	0.00	6.75	24.11
T_7	3.1	13.77	43.47	85.71	100
T_8	0.00	5.95	20.88	66.43	100
T_9	6.36	23.15	58.61	100	100
Mean	1.05	5.37	19.29	44.68	72.51
S.Em±	1.18	0.72	1.76	1.56	1.48
CD at 1%	NS	2.94	7.15	6.35	6.02

Initial value: 0%

Sensory evaluation

The data on organoleptic evaluation with respect to colour and appearance, firmness, juice flavour and overall acceptability of acid lime fruits in refrigerated condition as influenced by storage temperature and different packaging materials are presented in Table 5 to 8.

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 highest score was recorded in T_6 (5.17 at 80 DAS) followed by T_5 (3.57 at 80 DAS) as shown in plate 1. 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) [14, 10].

Table 5: Effect of zeolite based packages on colour and appearance of acid lime fruits stored at refrigerated conditions (10º C and 85-90% RH)

Treatments	Refrigerated storage							
	Days of storage							
	10	20	30	40	50	60	70	80
T_1	9.00	9.00	8.50	6.83	5.10	5.07	4.03	1.03
T_2	9.00	9.00	8.50	7.00	5.10	5.10	4.13	1.07
T_3	9.00	9.00	8.50	7.00	5.50	5.17	4.53	2.07
T_4	9.00	9.00	9.00	8.67	8.00	6.07	5.10	2.73
T_5	9.00	9.00	9.00	9.00	8.00	6.67	6.93	3.57
T_6	9.00	9.00	9.00	9.00	8.33	7.97	7.50	5.17
T_7	9.00	9.00	7.00	6.50	5.07	4.03	2.93	1.00
T_8	9.00	9.00	7.67	6.87	6.00	5.03	3.40	1.03
T_9	9.00	8.33	6.00	6.00	3.93	2.17	1.33	1.00
Mean	9.00	8.93	8.13	7.43	6.11	5.25	4.43	2.07
S.Em±	0.00	0.11	0.06	0.09	0.14	0.11	0.16	0.06
CD at 1%	NS	0.45	0.23	0.37	0.57	0.44	0.67	0.25

Initial value: 9.00

Table 6: Effect of zeolite based packages on firmness of acid lime fruits stored at refrigerated conditions (10º C and 85-90% RH)

Treatments	Refrigerated storage							
	Days of storage							
	10	20	30	40	50	60	70	80
T_1	9.00	9.00	9.00	7.10	6.17	5.00	4.50	1.03
T_2	9.00	9.00	9.00	7.20	6.27	5.07	4.80	1.33
T_3	9.00	9.00	9.00	7.23	6.50	5.17	5.00	1.60
T_4	9.00	9.00	9.00	8.07	7.17	6.17	5.17	3.67
T_5	9.00	9.00	9.00	9.00	7.83	7.33	6.93	3.90
T_6	9.00	9.00	9.00	9.00	8.00	8.00	7.50	5.23
T_7	9.00	9.00	8.00	7.00	5.07	4.10	2.17	1.00
T_8	9.00	9.00	8.00	7.07	6.17	5.00	3.50	1.50
T_9	9.00	9.00	7.67	5.77	3.07	2.33	1.67	1.00
Mean	9.00	9.00	8.63	7.49	6.25	5.35	4.58	2.25
S.Em±	0.00	0.00	0.06	0.10	0.17	0.15	0.20	0.23
CD at 1%	NS	NS	0.23	0.39	0.71	0.61	0.82	0.92

Initial value: 9.00

Firmness

The sensory scores of firmness of acid lime fruits as influenced by the different packaging material is presented Table 6. The results from the table revealed that, the score for firmness decreased as the storage period progressed in refrigerated condition. However, there was no significant difference observed among the treatments in refrigerated storage at 10 and 20 days of storage. At the end of storage highest score for firmness was given to treatment T_6 (5.23 at 80 DAS) followed by T_5 (3.90 at 80 DAS) whereas lowest score was observed in control and only CFB box (1.00). 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) [15, 9].

Table 7: Effect of zeolite based packages on juice flavour of acid lime fruits stored at refrigerated conditions (10º C and 85-90% RH)

Treatments	Refrigerated storage							
	Days of storage							
	10	20	30	40	50	60	70	80
T_1	9.00	9.00	9.00	8.40	6.83	6.83	6.00	1.33
T_2	9.00	9.00	9.00	8.47	7.07	6.97	6.03	1.67
T_3	9.00	9.00	9.00	8.50	7.17	7.07	6.13	1.83
T_4	9.00	9.00	9.00	8.83	7.83	7.33	6.33	2.60
T_5	9.00	9.00	9.00	8.90	8.07	7.50	7.00	3.50
T_6	9.00	9.00	9.00	9.00	8.50	7.67	7.17	5.13
T_7	9.00	9.00	7.33	6.93	6.83	6.83	6.00	1.00
T_8	9.00	9.00	7.33	7.03	7.17	7.00	6.27	2.00
T_9	9.00	9.00	7.00	6.97	5.83	5.00	2.67	1.00
Mean	9.00	9.00	8.41	8.11	7.26	6.91	5.96	2.23
S.Em±	0.00	0.00	0.08	0.08	0.17	0.11	0.15	0.25
CD at 1%	NS	NS	0.32	0.31	0.69	0.46	0.62	1.04

Initial value: 9.00

Juice flavour

The juice flavour of lime fruits decreased in lime fruits as storage period progressed in refrigerated storage conditions (Table 7). There was no significant difference observed among the treatments at 10 and 20 days of storage. But at the end of storage the highest score for juice flavour was given to treatment T6 (5.13 at 80 DAS) followed by T5 (3.50 at 80 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) [2] who found that decrease in flavour of lime fruits. The present findings are supported by Sonkar and Ladaniya (1999) [15].

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 in both ambient and refrigerated storage conditions. After 80 days of storage in refrigerated the highest overall acceptability score of acid lime fruits was accorded to T_6 (5.10) followed by T_5 (3.61). However, lowest score was given to control fruits (1.00).

Table 8: Effect of zeolite based packages on over all acceptability of acid lime fruits stored at refrigerated conditions (10º C and 85-90% RH)

Treatments	Refrigerated storage							
	Days of storage							
	10	20	30	40	50	60	70	80
T_1	9.00	9.00	8.83	7.44	6.03	5.63	4.84	1.16
T_2	9.00	9.00	8.83	7.56	6.14	5.71	4.99	1.48
T_3	9.00	9.00	8.83	7.58	6.39	5.80	5.22	1.72
T_4	9.00	9.00	9.00	8.52	7.67	6.52	5.53	2.43
T_5	9.00	9.00	9.00	8.97	7.97	7.17	6.96	3.61
T_6	9.00	9.00	9.00	9.00	8.28	7.88	7.39	5.10
T_7	9.00	9.00	7.44	6.81	5.66	4.99	3.70	1.00
T_8	9.00	9.00	7.67	6.99	6.44	5.68	4.39	1.51
T_9	9.00	8.78	6.89	6.24	4.28	3.17	1.89	1.00
Mean	9.00	8.98	8.39	7.68	6.54	5.84	4.99	1.96
S.Em±	0.00	0.07	0.22	0.31	0.48	0.63	0.62	0.31
CD at 1%	NS	0.30	0.90	1.27	1.94	2.55	2.53	1.22

Initial value: 9.00

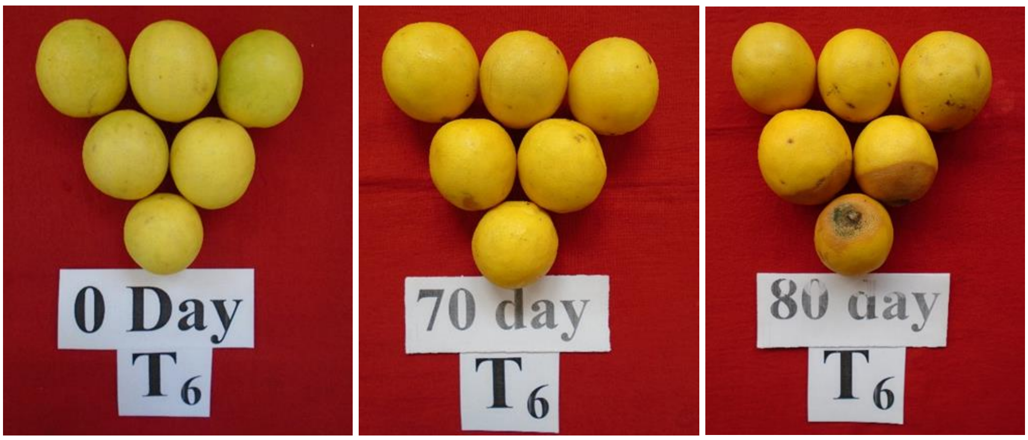

Fig 1: Comparison of fruits packed in Chlorine-zeolite-LDPE composite bag + CFB (T_6) from 0 day to 80 day in refrigerated condition

Fig 2: Comparison of fruits without any packaging material (Control-T_9) from 0 day to 80 day in refrigerated condition

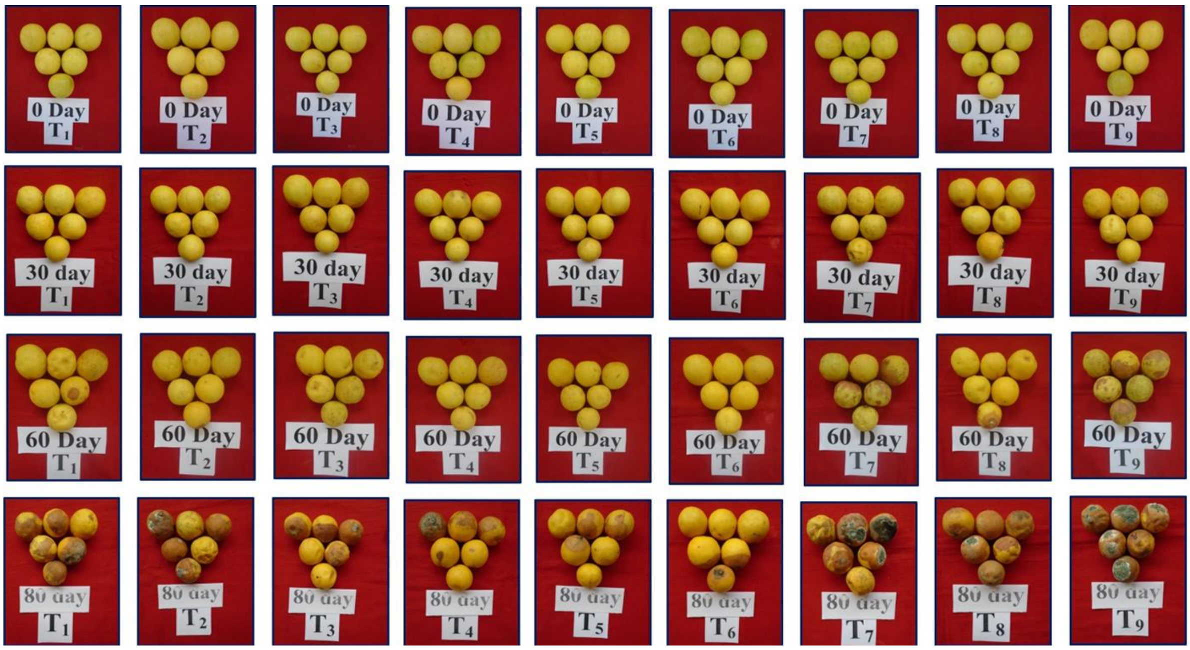

Plate 1: Effect of zeolite based packaging materials on shelf life and quality of acid lime in refrigerated storage (10^{o} C and 85 – 90% RH)

Conclusion

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 in refrigerated 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 40 days more compare to control (36 days) with maintaining all sensory characters at the end of storage.

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