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Effect of antimicrobial compounds synergized zeolite-LDPE composite bags on organoleptic quality of sapota fruits under refrigerated condition

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Abstract
This experiment was conducted in the Department of Post-harvest Technology, College of Horticulture, University of Horticultural Sciences, Bagalkot during the year 2018-19. In this experiment, banana fruits were packed in seven packaging treatments (T_1-Silver-zeolite-LDPE composite bag, T_2-Zeolite-LDPE composite bag, T_3-Chlorine-zeolite-LDPE composite bag, T_4-Silver-zeolite-LDPE composite bag + CFB, T_5-Zeolite-LDPE composite bag + CFB, T_6-Chlorine-zeolite-LDPE composite bag + CFB and T_7-Only CFB) were compared with control (T_8) to know their efficacy in maintaining the organoleptic qualities of sapota fruits refrigerated (13°C) conditions. Sapota fruits packed in T_6-Chlorine-zeolite-LDPE composite bag + CFB scored maximum scores in terms of appearance (freshness/shrinkage) of fruit, pulp colour, mouth feel (firmness) of pulp, taste and flavour and overall acceptability among the treatments during storage of 21 days.

Keywords: Zeolite, synergized, LDPE (low density poly ethylene), days after storage (DAS)

1. Introduction

The sapota (*Manilkara achras*) is highly delicious, nutritive fruit valued for its mellow and sweet pulp with granular texture and pleasant aroma. It is native of southern parts of Mexico and now it has been adopted in many countries of tropical and subtropical climate. The fruit is a fleshy berry, ellipsoidal, conical, or oval and contains one or two shiny black seeds. It weighs about 70-300 g, has a dull brown color and thin skin with yellowish, light brown or red pulp. The fruit is commonly known as chikku in India and mainly cultivated for its fruit value; while in some countries like Southeast Mexico, Guatemala, it is commercially grown for the production of chuckle that is coagulated milky latex obtained from the bark of sapota tree. The chuckle is used as the principal ingredient of chewing gum. India is the leading producer of sapota in the world with an annual production of 350.33 thousand metric tons (Anonymous 2018) [1]. The popularity of the crop is increasing due to high production per unit area and continuous fruiting throughout the year.

From nutritional point of view, sapota is the cheapest source of sugars. Every 100 g of sapota flesh contains 73.7 % water, 1.1 % fat, 0.7 % protein, 21.4 g carbohydrate, 28 mg calcium, 27 mg phosphorus, 2 mg iron and 6 mg ascorbic acid (Bose *et al*., 1992) [2]. Sapota, when fully ripe, is delicious and is eaten as dessert fruit. It is also made into sherbet and halwa (Singh *et al.*, 1963) [16]. The dried sapota pieces could be made into edible powder and the powder could be utilized for making milk shake and sweets (burfi) (Joshi *et al.*, 1993) [6].

As sapota fruits classified under extremely high ethylene producers, they are highly perishable in nature, ripe quickly, lose moisture rapidly, spoiled faster and achieve senescence rapidly after harvest (Singh *et al.*, 2017) [17]. The level of ethylene production in sapota fruits increased slowly from the beginning of ripening and reached its peak at 144 hours, which was followed by a decline (Selvaraj and Pal, 1984) [15].

Ethylene is a gaseous plant hormone that plays a major role in the regulation of the metabolism of harvested horticultural crops at very low concentrations (Zhang *et al.*, 2012) [18]. The post-harvest life of both climacteric and non-climacteric fruits can be influenced by ethylene. This hormone affects their quality attributes, the development of physiological disorders and post-harvest diseases (Ernst, 2011) [4]. Effects of ethylene on quality attributes *viz.*, external appearance, texture, flavour and nutritive value of fruits have been extensively reported (Saltveit, 1999) [13]. Any closed environment such as truck trailer, shipping container, warehouses, cold rooms and consumer size package results in increase in concentration of ethylene. Therefore, the need to control ethylene activity to extend the post-harvest life of fruits through improvement in packaging, introducing anti-ethylene substances like zeolite is greater than ever.

Zeolite is a large and diverse class of volcanic aluminosilicate crystalline material which has many useful applications (Khosravi *et al.*, 2015) [8]. The use of zeolite as an adsorbent has started in 1930s followed by Milton, who used zeolite for air purification (Kamarudin, 2006) [7]. 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 and ethylene (Khosravi *et al.*, 2015) [8]. It has a rigid, three dimensional crystalline structure consisting of a network of interconnected channels and cages. Water moves freely in and out of these pores, but the zeolite framework remains rigid (Kamarudin, 2006) [7]. Moreover, the incorporation of antimicrobial compounds into zeolite-LDPE composite bags can further improve the physical, mechanical and biological properties of the bag (Lee *et al.*, 2017) [10].

Among inorganic antimicrobial agents, chlorine and silver compounds could highly inhibit microbial growth and show strong biocidal effects on many species of bacteria including *Escherichia coli* (Kim *et al.*, 2007) [9]. The interaction of chlorine and silver ions with microbial cytoplasmic components and nucleic acids can inhibit the respiratory chain enzymes and interferes with the membrane permeability, limiting the development of bacteria, fungi and yeast (Russel and Hugo, 1994) [12]. In this study, the effect of antimicrobial compounds synergized zeolite-LDPE composite bags packaging on the postharvest quality of *M. achras* fruits was evaluated for the first time.

2. Materials and methods

2.1 Materials and treatments

Sapota fruits (cv. Kalipatti) of uniform size and shape, free from any visible damage, scratches and decay were selectively harvested manually at right maturity stage and brought to the laboratory. Then, the plastic crates containing fruits were placed in the cold room for pre-cooling by room cooling method at 13ºC for 12 hours. Then fruits were packed in antimicrobial compounds synergized zeolite-LDPE composite bags *viz.*, Silver-zeolite-LDPE composite bag (T_1), Zeolite-LDPE composite bag (T_2), Chlorine-zeolite-LDPE composite bag (T_3), Silver-zeolite-LDPE composite bag + CFB box (T_4), Zeolite-LDPE composite bag + CFB box (T_5), Chlorine-zeolite-LDPE composite bag + CFB box (T_6), Commercially used CFB (T_7) and Control (without any package) (T_8) @ 6 fruits/treatment and stored under refrigerated (13°C) conditions.

Each pack of fruits was kept undisturbed until the scheduled date of observation. Thus, there were so many numbers of packs under each treatment as the number of times the fruits were observed at scheduled interval. Sapota fruits were observed for 8 times for each treatment. There were 8 packs each containing 6 fruits for each treatment. All the fruit-packs removed from storage condition on scheduled day of observation were used to record different observations. Thus, each pack in the storage condition passed through the storage time undisturbed until it was finally taken out to observe for orgaoleptic evaluation

2.2 Sensory evaluation

The sensory evaluation of sapota fruits under study was carried out by a semi-trained panel consisting of Teachers and Post-Graduate students of College of Horticulture, Bagalkot with the help of nine point hedonic rating scale (1 = dislike extremely, 2 = like only slightly, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much and 9 = like extremely). Sensory parameters considered in evaluation included appearance (freshness/shrinkage) of fruit, pulp colour, mouth feel (firmness) of pulp, taste and flavour and overall acceptability.

2.3 Statistical analysis

The data of experiment 1 and 2 were analyzed as applicable to completely randomized design (CRD). Statistical analyses of experiments were performed using Web Agri Stat Package (WASP) Version 2. The level of significance used in 'F' and't' was p=0.01 and also p=0.05 for some parameters. Critical difference values were calculated whenever F-test was found significant.

3. Result and Discussion

Sapota fruits in this experiment had reached the edible ripe stage at 15 DAS. Hence, sapota fruits were observed for sensory parameters from 15 DAS, but not before.

3.1 Appearnace (Freshness/Shrinkage) of fruit

Sensory evaluation for appearance of sapota fruits revealed significant differences among the treatments (Table 1). Sensory score for this parameter was found to decrease gradually along the period of storage of 21 days. Significantly higher score was noted in T_6 throughout the storage period (15 DAS-9.00; 18 DAS-9.00 and 21 DAS-8.52). However, this treatment was on par with all other treatments except T8 at 15 DAS and with T_3, T_4, and T_5 at 21 DAS. But at 18 DAS, all the surviving treatments remained statistically non-significant. On the contrary, the treatment T_8 obtained significantly minimum score at15 DAS (7.02). However, the fruits of the treatments T_7 and T_8 did not survive after 15 DAS.

Under refrigerated storage, appearance among all the treatments was highly acceptable up to 15 DAS. But, fruits of T_7 and T_8 could not be evaluated at 18 DAS as they were beyond edible quality after 15 DAS (Table 1). Comparatively higher score at 18 DAS obtained by the fruits packed in zeolite-LDPE bags (T_1 to T_6) could be due to the reduced weight loss resulting from reduced respiration and loss in weight. This is supported by the observations of Hailu *et al.* (2012) [5] in banana fruits packaged along with ethylene scrubbers ($KMnO_4$). Controlled atmosphere storage or modified atmosphere packaging reatins turgidity and freshness for longer period (Salunkhe and Desai, 1984) [14].

However, fruits of the treatment T_8 were unfit for consumption after 15 and T_2, T_7 after 18 DAS respectively.

3.2 Pulp Colour

The data revealed non-significant differences for pulp colour among sapota fruits of different treatments at 15 DAS, but showed significant differences at 18 and 21 DAS (Table 1). At 15 DAS all the treatments received maximum score (9.00).

Highest score was noted in T_6 at 18 and 21 DAS (9.00 and 8.71 respectively). However, this treatment was on par with all the surviving treatments at 18 DAS (T_1, T_2, T_3, T_4 and T_5) and at 21 DAS (T_1, T_3, T_4 and T_5). The treatments T_7 and T_8 did not survive after 15 DAS.

Flesh colour of sapota fruits changes from pale yellow or pale pink to orange or dark brown colour upon ripening (Perez, 1999)[11]. Orange colour is due to the synthesis of carotenoids and brown colour is due to synthesis of phenols during ripening (Casas Alencaster, 1977)[3]. However, comparatively higher pulp colour score obtained by the fruits packed in zeolite-LDPE bags (T_1 to T_6) beyond 15 DAS could be reasoned to effectiveness of porous zeolite in adsorbing ethylene thereby delaying synthesis of carotenoids and phenols in fruit pulp (Khosravi *et al.*, 2015)[8]. Reduced score in T_7 and T_8 at 15 DAS could be due to abundance of ethylene around the fruits causing rapid ripening and earlier loss of shelf life.

3.3 Mouth feel (firmness) of pulp

The data revealed non-significant differences for mouth feel of pulp among sapota fruits of different treatments at 15 DAS, but showed significant differences at 18 and 21 DAS (Table 2). Irrespective to treatments, sapota fruits received maximum score (9.00) at 15 DAS. The treatment T_6 received maximum score for mouth feel (15 DAS-9.00; 18 DAS-9.00 and 21 DAS-8.61). However, this treatment was on par with all the surving treatments (T_1, T_2, T_3, T_4 and T_5) at 18 DAS and with, T_3, T_4, and T_5 at 21 DAS. On the contrary, the treatment T_7 and T_8 became unfit for consumption after 15 DAS and T_2 after 18 DAS due to loss of shelf life.

Under refrigerated storage, fruits under all the treatments received mouth-feel score of 9.00 at 15 DAS. Comparatively higher score at 18 DAS obtained by the fruits packed in zeolite-LDPE bags (T_1 to T_6) could be due to the reduced weight loss resulting from reduced respiration or lower enzyme activity as observed by Hailu *et al.* (2012)[5]. Modified atmosphere packaging inhibits the breakdown of pectin substances and retains firmer texture in fruits for a longer period (Salunkhe and Desai, 1984)[14]. However, fruits of the treatment T_8 (control) became unfit for consumption after 15 and T_2 (zeolite-LDPE composite bag) and T_7 (only CFB) after 18 DAS respectively.

Table 1: Effect of zeolite based packages on appearance (freshness/Shrinkage) of fruit and colour of pulp of sapota fruits under refrigerated condition (13 °C)

Treatments	Appearance (freshness/Shrinkage) of fruit				Pulp colour			
	15 DAS	18 DAS	21 DAS	Mean	15 DAS	18 DAS	21 DAS	Mean
T_1	9.00^a	8.91^a	7.21^b	8.37	9.00	9.00^a	7.54^{ab}	8.51
T_2	8.65^a	7.94^a	**	5.53	9.00	8.89^a	**	5.96
T_3	9.00^a	9.00^a	8.06^{ab}	8.68	9.00	9.00^a	7.88^{ab}	8.62
T_4	9.00^a	9.00^a	8.39^{ab}	8.79	9.00	9.00^a	8.54^a	8.84
T_5	9.00^a	9.00^a	8.26^{ab}	8.75	9.00	9.00^a	8.12^a	8.70
T_6	9.00^a	9.00^a	8.52^a	8.84	9.00	9.00^a	8.71^a	8.90
T_7	8.16^a	**	**	2.72	9.00	**	**	3.00
T_8	7.02^b	**	**	2.34	9.00	**	**	3.00
Mean	8.60	6.60	5.05		9.00	6.73	5.09	
S.Em±	0.35	0.45	0.50		0.00	0.20	0.50	
CD@5%	1.06	1.36	1.22		NS	0.61	1.49	

T_1- Silver-zeolite-LDPE composite bag
T_2 - Zeolite-LDPE composite bag
T_3 - Chlorine-zeolite-LDPE composite bag
T_4 - Silver-zeolite-LDPE composite bag + CFB
T_5 - Zeolite-LDPE composite bag + CFB
T_6 - Chlorine-zeolite-LDPE composite bag + CFB
T_7 - Only CFB
T_8 - Control
** - 100% Spoiled fruits

3.4 Taste and flavor

Sensory score for taste and flavour of sapota fruits among different treatments were similar at 15 and 18 DAS (9.00), but showed significant differences at 21 DAS (Table 2). Maximum score at 21 DAS was noted in T6 (8.57). However, this treatment was on par with T1, T2, T3, T4 and T5 at 18 DAS and only with T1 T3 and T4, at 21 DAS. The treatments T7 and T8 after 15 DAS and T2 after 18 DAS reached the unacceptable stage.

Sapota fruits of T8 (Control) had lost shelf life after 5 days under ambient condition and after 15 DAS under refrigerated condition. Maximum score was observed in T6 (Chlorine-zeolite-LDPE composite bag + CFB) both under ambient (6 DAS-8.81) and refrigerated condition (21 DAS-8.57). Zeolite in the package is responsible for slow ripening of bananas leading to retention of edible life in this treatment. However, all zeolite-LDPE bags alone (T1, T2, T3) or in combination with CFB box (T4, T5, T6) obtained statistically similar score indicating rhythm in taste and texture contributing factors under both conditions of storage.

3.5 Overall acceptability

The data revealed non-significant differences for overall acceptability among sapota fruits of different treatments at 15 DAS, but showed significant differences at 18 and 21 DAS (Table 3). At 15 DAS, fruits of the entire treatments received maximum score (9.00). At 18 DAS, fruits of surving treatments T1, T2, T3, T4, T5 and T6 remained statistically on par. However, the treatment T6 scored maximum for overall acceptability (8.60) at 21 DAS. It was on par with T3, T4, and T5, but showed significant difference with T1 (7.50).

This could be attributed to the ethylene adsorbing effect, antimicrobial effect and modified atmosphere effect benefitting in extending the acceptable shelf life. However, the score in refrigerated condition ranged from 7.50 (T1) to 8.60 (T6). The higher score observed under refrigerated storage could be reasoned to the effect of low temperature in addition to the beneficial effect of packaging material on banana fruit quality.

4. Conclusion
Sensory evaluation (9 Point hedonic scale) revealed significantly higher score for appearance in T6 (15 DAS-9.00; 18 DAS-9.00 and 21 DAS-8.52). However, sensory score for pulp colour, mouth feel as well as taste and flavor did not differ significantly. Overall acceptability score varied significantly among the treatments with the maximum being recorded in T6 (15, 18 DAS-9.00, and 21 DAS-8.60).

Table 2: Effect of zeolite based packages on mouth feel (firmness) of pulp and taste and flavour of sapota fruits under refrigerated condition (13 °C)

Treatments	Mouth feel (firmness) of pulp				Taste and flavour			
	15 DAS	18 DAS	21 DAS	Mean	15 DAS	18 DAS	21 DAS	Mean
T_1	9.00	9.00[a]	7.41[b]	8.47	9.00	9.00	7.84[ab]	8.61
T_2	9.00	8.57[a]	**	5.85	9.00	9.00	**	6.00
T_3	9.00	9.00[a]	7.69[ab]	8.56	9.00	9.00	7.99[ab]	8.66
T_4	9.00	9.00[a]	8.45[ab]	8.81	9.00	9.00	8.29[ab]	8.76
T_5	9.00	9.00[a]	7.58[ab]	8.52	9.00	9..00	7.26[b]	8.13
T_6	9.00	9.00[a]	8.61[a]	8.87	9.00	9.00	8.57[a]	8.85
T_7	9.00	**	**	3.00	9.00	**	**	3.00
T_8	9.00	**	**	3.00	9.00	**	**	3.00
Mean	9.00	6.69	4.96		9.00	6.42	4.99	
S.Em±	0.00	0.35	0.20		0.00	0.00	0.35	
CD@5%	NS	0.61	1.06		NS	NS	1.06	

T1- Silver-zeolite-LDPE composite bag
T2 - Zeolite-LDPE composite bag
T3 - Chlorine-zeolite-LDPE composite bag
T4 - Silver-zeolite-LDPE composite bag + CFB
T5 - Zeolite-LDPE composite bag + CFB
T6 - Chlorine-zeolite-LDPE composite bag + CFB
T7 - Only CFB
T8 - Control
** - 100% Spoiled fruits

Table 3: Effect of zeolite based packages on overall acceptability of sapota fruits under refrigerated condition (13°C)

Treatments	Overall acceptability			
	15 DAS	18 DAS	21 DAS	Mean
T_1	9.00	8.97[a]	7.50[b]	8.49
T_2	9.00	8.60[a]	**	5.86
T_3	9.00	9.00[a]	7.90[ab]	8.63
T_4	9.00	9.00[a]	8.41[ab]	8.80
T_5	9.00	9.00[a]	7.80[ab]	8.60
T_6	9.00	9.00[a]	8.60[a]	8.86
T_7	9.00	**	**	3.00
T_8	9.00	**	**	3.00
Mean	9.00	6.69	5.02	
S.Em±	0.00	0.28	0.35	
CD@5%	NS	0.86	1.06	

T1 - Silver-zeolite-LDPE composite bag
T2 - Zeolite-LDPE composite bag
T3 - Chlorine-zeolite-LDPE composite bag
T4 - Silver-zeolite-LDPE composite bag + CFB
T5 - Zeolite-LDPE composite bag + CFB
T6 - Chlorine-zeolite-LDPE composite bag + CFB
T7 - Only CFB
T8 - Control

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