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Effect of different edible coatings on the quality and shelf life of chinese meyer lemon *(Citrus meyer* L.)

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Key words: Chinese Meyer Lemon, Shelf life, Fruit quality, Garlic extract solution, Honeybee wax solution, Aloe vera gel solution, Sugarcane wax solution.

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Abstract

Chinese meyer lemon were treated with four different solutions (garlic extract, honeybee wax solution, *Aloe vera* gel solution and sugarcane wax solution) as an edible coating before storage. Analytical determinations were made for about 10 days at room temperature. The changes in fruit quality parameters related to lemon postharvest ripening, such as weight loss, softening, fruit firmness, total soluble solids, browning ratio, pH and shelf life and colour changes were significantly evaluated. The best antifungal and antimicrobial agent was found to be 15% *Aloe vera* gel solution. It aided in preservance of moisture and also acted as anti-browning againt. *Aloe vera* gel can be used for commercial application and as alternative of the use of postharvest chemical treatments. Garlic extract solution followed by *Aloe vera* showed excellent results in terms of preserving food without the proliferation of microbes and fungi. On the contrary, sugarcane wax solution and honeybee wax solution showed poor results.

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Introduction

The lemon belongs to the kingdom Plantae and the family Rutaceae. The order in scientific classification is spindales, whereas the genus 'citrus' and specie 'limon' is worldwide classified. The lemon, *Citrus lemon* (L.) is a species of a small evergreen tree of the family Rutaceae. It is local to South Asia, primitively northeast India. In temperate climates lemon is not hardy all year as it requires a base temperature of practically 7°C (45 °F), however turned out to be hardier as it matures (Martin, 2008). The varieties of lemon may include (Sauls, 1998) Chinse meyer lemon, Kaghzi, Lazeem, Desi kaghzi, and Eurica. To conduct this research, Chinese meyer lemon is used. Citrus × meyeri, the Meyer lemon, is a hybrid native fruit of China that is formed by the crossing of citron and mandarin/pomolio.

The height of trees varies from 6-10 feet with light green leaves having a shiny texture. The fruit is a true round lemon yellow and less acidic. The fluorescence varies from white to purple. It is mostly considered an ornamental plant and grows well in a warm climate (Harley *et al*., 2006). *Citrus meyeri* L. is the most significant fruit crop of Pakistan among all fruit. For its nutritive worth and market significance, it is the most important fruit of tropical and sub-tropical zones of Pakistan. Chilling injury and red blotch are major disorders that occur when the fruit is taken out from the cold storage during the retail sale period (Abed EL-Hakim, 2017). Cold storage is used for maintaining its quality and quarantine measures, but it is an expensive method. As most of the farmers in Pakistan are small-scale farmers, therefore, it is a dire need of the hour to find out the cheaper methods for fruit and vegetable preservation.

It is necessary to find out the post-harvest techniques at room temperature (Ghosh, 2015). The innovations that are utilized contemporarily for promoting shelf life are chemical treatments, controlled climate, consumable coatings, low and high temperatures, hydrothermal and plastic packaging treatments, MAP (modified atmospheric packaging), natural compounds, and UV (Dávila-Aviña, 2014).

Major Post-harvest losses of lemon are because of weight loss, fungal diseases, physiological disorders i.e. browning of product, etc., and quarantine pests. Conventional methods of treating fruit with chemical fungicides, synthetic waxes, or their combinations are used commonly (Arpaia, 1994). But the repetition of these treatments may lead to serious health and environmental consequences. This increases the demand for such treatments that include non-polluting alternatives and healthy edible coatings with antifungal and antimicrobial effects (Palou, 2015).

The most widely used treatments are edible coatings and chemical treatments. Bio-edible coatings are used as a film covering protection that fastens or postpones the maturation or senescence of the product to further enhance the food quality (Sudhaa *et al*., 2007). Among all coatings, solutions of bumblebee wax, sugarcane wax, and garlic extract, and aloe vera gel are significant because of their restorative and medicinal value. The coatings of therapeutic significance have been picked in light of the fact by implication, likewise, influences human well-being (Abhay *et al*., 2012).

This research work aimed to study the effectiveness of 4 different edible coatings as emulsions on the post-harvest shelf life, and the nutritional quality of lemon that could be greatly promising.

Material and methods

The fruits (*Citrus Meyer* L.) were manually harvested at full yellow color, uniform size and freedom of defects, from Jinnah Park, Lahore, and immediately transported to the postharvest laboratory at the University of Punjab, Institute of Agricultural Sciences. The fruits were separated into five different lots, each lot comprising of eighteen fruit of uniform size, shape, and appearance, and these were further divided into three subgroups indicating replication each having six fruits. Triplicated research study designed in CRD (Completely Randomized Design) continued for 10 days with an interval of two days. Four treatments were used with one control condition as shown in Table 1. All the lots were dipped in their

respective treatment for 5 minutes (Valverde, 2005) and kept at room temperature.

Preparation of stock solutions of edible coating

Aloe vera gel solution: For the preparation 15 % of *Aloe vera* gel solution, 75 g of aloe vera gel was added in distilled water. After this volume was increased up to mark '500 mL' (Brown, 1994).

Garlic extracts solution: For preparation of 30 % solution of garlic extract, 300 g of garlic were crushed and dipped in 1 L ethanol for 2 days at 4 ◦C (Daniel, 2014).

Honeybee wax solution: For 15 % of Honeybee wax solution, 75 g of Honeybee wax (melted liquid honeybee wax) added in distilled water. After this volume was increased up to mark '500 mL (Brown, 1994).

Sugarcane wax solution: To make a 15 % Sugarcane extract solution, 75 g of dry Sugarcane extract was mixed with 100mL^{-1} of distilled. (Islam, 2016)**.**

Sample preparation

For sample preparation, 50 grams of lemon juice was weighed shifted to the blender (National 1000W: MT969) 100mL of distilled water was added to prepare the juice sample.

Physiochemical parameters

Color change: The change of peel color during storage was determined by visual numerical rating developed by J.H Hatt, 1908 (Yellow, Dark Yellow, Lime, Brownish-yellow, and Brown).

Browning: Browning ratio was measured by using the formula:

(Brown lemon in the lot ÷ total number of lemons in the lot) × 100

Size change: Change of size was observed by the naked eye and as the moisture losses, the size of the product reduces which is further described in the measuring of loss of water.

Weight loss: All the fruit were weighed before the application of treatments by using an electronic weighing balance (model: HCB60.2 Hand) then after every 2 days' interval till 10 days.

For weight loss measurement, the method of (Van Dijk, 2006) was followed with a little amendment. Instead of placing fruit back to its original place, one of those was taken for further analysis by juice preparation. The weight of each fruit was measured from the replicates and then the average was calculated.

Pulp pH: pH meter (Model: pHep Tester-HI98107) was used for this purpose as described by (AOAC, 2000). pH meter was dipped in the juice of lemons and readings were noted according to a pre-decided schedule. The comparison was done by using the chart created by (Anon, 1962).

Shelf life: The shelf life of lemon was observed by measuring the quantitative and quality changes that occurred during the storage period.

Statistical analysis

Fisher's analysis of variance (ANOVA) techniques was used to statistically analyze the results and their means were compared by LSD test (Least Significance Difference) at a: 0.05 as described by Steel *et al*., (1997). The statistical analysis was done by using Microsoft Excel (Office 365).

Results and discussion

Measurement of moisture conservation

During entire length of experiment moisture loss in (control) samples was found to be higher than that of coated samples.The weight of lemons was measured with intervals of 2 days for a total of 10 days as presented in (Table 2). The weight value of lemons is 18.31 for the control treatment, 18.47 for sugar cane wax solution followed by the honeybee wax solution with 18.84. But it was observed that the maximum moisture retention was preserved in the lemons dipped in the solutions of garlic extract (21.29) and *Aloe vera* gel (21.87) (Fig. 1).

Table 1. Different treatments and their percentages of solution used.

Treatment no.	Type	Percentage (%)
T_0	control	_____
T_1	Garlic extract solution	30
T_2	Honeybee wax solution	15
T_3	aloe vera gel solution	15
T_4	sugarcane wax solution	15

Table 2. Results of moisture conservation of lemon.

Treatment	Honeybee wax Solution			Sugarcane wax solution			Aloe vera gel solution			Garlic extract			Control		
Days	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3
Day 0	24.1	17.46	19.75	16.75	19.75	19.84	21.84	22.80	21.15	22.35	23.0	21.05	22.93	22	14.70
Day 2	24.5	18	20	17.75	20.65	20.78	22	23	21.57	22.56	23.20	21.32	22.93	22	14.70
Day 4	22	17.6	19.03	17.45	20.37	20.56	21.97	22.97	21.48	22.01	23.00	21.00	21.76	20.66	14.30
Day 6	20	16.92	18.45	16.73	19.00	19.01	21.80	22.70	21.40	21.98	22.65	20.54	20.60	19.95	13.91
Day 8	18.20	16.00	17.98	16.34	18.63	17.98	21.00	22.64	21.34	20.37	21.56	19.01	19.45	18.90	12.54
Day 10	17.69	15.12	16.56	15.99	18.02	17.02	20.94	22.57	21.29	19.60	20.1	18.09	18.98	17.48	12.00

The boxplot graph for comparing all the result also shows that *Aloe vera* gel extract treated lemons retain maximum moisture (Fig. 2).

There is negative correlation between moisture content and no. of days meaning that as days passes there is decrease in moisture content (Table 3). The *p*-value =0.0257 predicted that there was significant difference among th all treatments (Table 4). Thus, the results showed that the aloe vera gel solution is the most suitable dipping solution to retain moisture. Aloe vera gel solution helps to improve the shine of the lemon surface, reduces moisture loss, and promotes firmness of the fruit.

It helps in controlling the respiration rate of the product and regulates maturation development (Jawadul Misir, 2014,). Hence *Aloe vera* gel solution has been proved to be the best solution for conserving moisture in the produce. (Cohen, 1994).

Table 3. Regression analysis of moisture conservation of lemon.

Contol MC	Honey MC	Sugar MC	Aloe vera MC	Garlic MC
y = -0.8923x + 21.125	y = -0.4046x + 21.979	y = -0.4651x + 20.105	y = -0.012x + 21.789	y = -0.2937x + 23.375
R^2 = 0.9604	R^2 = 0.9371	R^2 = 0.689	R^2 = 0.0044	R^2 = 0.8095

Table 4. ANOVA of moisture conservation of lemon.

		Moisture				
SOV	DF	SS	MSS	F	P	??
data$Treatment	4	63.84	15.961	4.428	0.0257	*
Residuals	10	36.04	3.604			

Table 4. Continued.

Coatings	data$moisture	groups
AloeVera	21.6	a
Garlic	19.26333	ab
Sugarcane	17.01	ab
Honey	16.45667	b
Control	16.15333	b

Browning ratio

The browning ratio of lemons was measured by checking out the brown lemons and removing them from each lot (Table 5). The browning ratios of lemon dipped were 37.22, 29.44, 15.73, 8.7, 4.81 for control, honeybee wax solution, sugarcane wax solution, garlic extract and aloe vera gel solution respectively (Fig. 3). Thus the highest browning ratio was found in the control treatment and lowest in aloe vera gel treated lemons.

Table 5. Results of Browning ratio of different treatments on lemon.

Treatment	Honeybee wax Solution			Sugarcane wax solution			Aloe vera gel solution			Garlic extract solution			Control		
Days	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3
Day 0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
Day 2	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
Day 4	20	00	00	00	00	16.66	00	00	00	00	00	00	16.66	16.66	16.66
Day 6	25	16.6	33.3	16.66	16.66	40	00	00	00	00	00	00	40	40	40
Day 8	33.33	20	25	20	40	33.33	16.66	00	00	16.66	16.66	33.33	66.66	66.66	66.66
Day 10	50	50	66.6	25	25	50	20	16.66	33.33	20	20	50	100	100	100

Table 6. Regression analysis of browning ratio of different treatments of lemons.

Control Browning Ratio	Honey Browning Ratio	Sugarcane Browning Ratio	Aloe vera Browning Ratio	Garlic Browning Ratio
y = 20.666x - 35.112	y = 14.887x - 22.666	y = 7.9677x - 12.149	y = 3.8086x - 8.5167	y = 6.1894x - 12.961
R^2 = 0.9332	R^2 = 0.8588	R^2 = 0.9101	R^2 = 0.5821	R^2 = 0.714

The boxplot graph comparing all data also showed that browning ratio measured at day 10 was highest in control and lowest in aloe vera gel treated lemons (Fig. 4). The regression analysis presented that there was positive correlation between browning ratio and no. of days, which means that as days passed the browning ratio increased (Table 6).

Table 7. ANOVA of browning ratio of different treatments on lemon.

		Browning				
SOV	DF	SS	MSS	F	P	significant
data$Treatment	4	10941	2735.2	27.19	2.36E-05	***
Residuals	10	1006	100.6			

Table 7. Continued.

Treatments	data$browning	groups
Control	100	a
Honey	55.53333	b
Sugarcane	46.66667	bc
Garlic	30	bc
AloeVera	23.33	c

The value of p=2.36E-05 means that data was statistically very significant (Table 7). Overall results depicted that browning was increasing with the least rate in aloe vera gel treated lemons as compared to control and other treatments (Fig. 5). Thus, aloe vera gel solution can delay oxidative browning and micro-organisms proliferation. *Aloe vera* gel, is mainly polysaccharides (Ni *et al.*, 2004) ,was highly effective as a browning barrier without the lipid incorporation. It reduces moisture loss by keeping the intact structure of fruit peel (Supapvanich *et al.*, 2016). Hence, ALV application could be considered as a commercial treatment of browning reduction in lemon fruit (Sajid *et al.*, 2019).

Table 8. Results of pH of the pulp of lemons.

Treatment	Control			Garlic extract			Aloe vera gel solution			Sugarcane wax solution			Honeybee wax solution		
Days	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3	R_1	R_2	R_3
Day 0	2.0	1.97	1.89	2.10	2.00	1.99	1.98	1.78	2.00	1.69	1.94	1.87	1.98	1.96	2.03
Day 2	2.0	1.90	1.74	2.00	1.96	1.84	1.98	1.78	1.99	1.69	1.94	1.87	1.98	1.96	2.03
Day 4	1.97	1.84	1.65	1.95	1.94	1.76	1.96	1.72	1.97	1.66	1.91	1.83	1.78	1.87	1.98
Day 6	1.87	1.79	1.43	1.87	1.80	1.63	1.93	1.69	1.94	1.61	1.87	1.80	1.55	1.56	1.86
Day 8	1.76	1.63	1.30	1.76	1.76	1.50	1.91	1.64	1.91	1.57	1.84	1.77	1.43	1.46	1.76
Day 10	1.54	1.45	1.29	1.65	1.69	1.46	1.87	1.62	1.87	1.55	1.82	1.73	1.33	1.34	1.54

Table 9. Regression analysis of pH of pulp of lemon.

Garlic PH	Honey PH	Sugar PH	Aloe vera PH	Control PH
y = -0.0871x + 2.1167	y = -0.1283x + 2.1907	y = -0.0991x + 1.8753	y = -0.0286x + 1.96	y = -0.1369x + 2.094
R^2 = 0.9926	R^2 = 0.9546	R^2 = 0.9568	R^2 = 0.9785	R^2 = 0.9747

Table 10. ANOVA of pH of the pulp of lemons.

			PH			
SOV	DF	SS	MSS	F	P	significant
data$Treatment	4	0.3365	0.08413	4.955	0.0183	*
Residuals	10	0.1698	0.01698			

Table 10. Continued

Coatings	data$dph	groups
AloeVera	1.786667	a
Sugarcane	1.7	ab
Garlic	1.6	ab
Control	1.426667	b
Honey	1.403333	b

Pulp pH

The pH of lemon is measured to be 2.0 approximately (Strazzer, 2019). But the decrease in the moisture content increases the acidic content of ascorbic acid in the produce. Whereas in the experimental lot, it was observed that the pH reduces by time and the data of measurement of pH was taken by the interval of two days in ten days (Table 8).

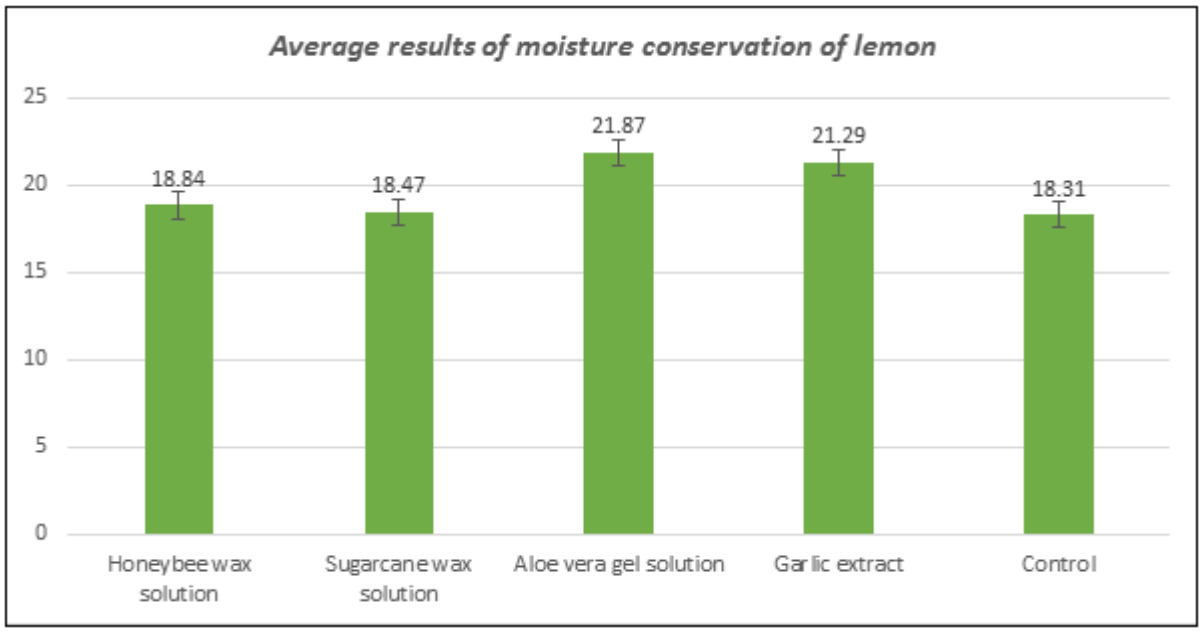

Fig. 1. The average result of the moisture conservation of lemons for 10 days of storage at room temperature of control and coated lemons with (30%) Garlic extract solution, (15%) Honeybee wax solution, (15%) aloe vera gel solution, (15%) sugarcane wax solution at ambient condition (26 ± 7 °C and 73± 9% RH).

The average results showed that the pH variation in the lemons dipped in aloe vera gel was the minimum with pH value 1.86 while 1.81,1.77,1.74 and 1.72 was observed for garlic extract, sugarcane extract, honeybee extract and control respectively (Fig. 6). The boxplot graph comparing all the treatments and control also depicted that pH change is maximum in control and minimum in aloe vera gel treated lemons (Fig. 7).

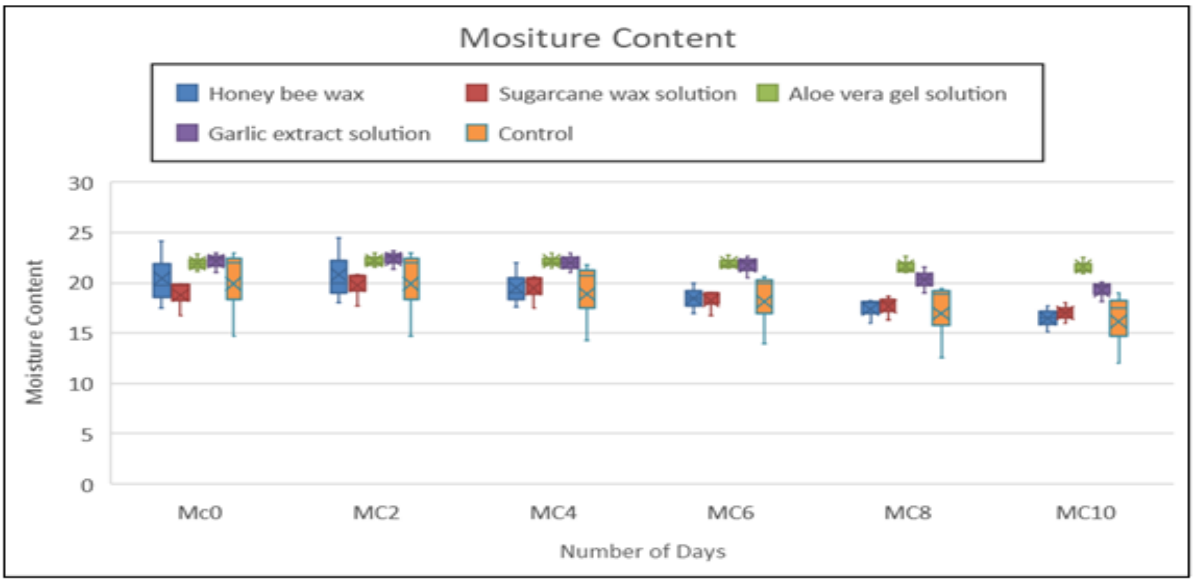

Fig. 2. Scores of visual aspects of moisture loss after 0, 2, 4, 6, 8 and 10 days of storage at room temperature of control and coated lemons with (30%) Garlic extract solution, (15%) Honeybee wax solution, (15%) aloe vera gel solution, (15%) sugarcane wax solution at ambient condition (26 ± 7 °C and 73± 9% RH).

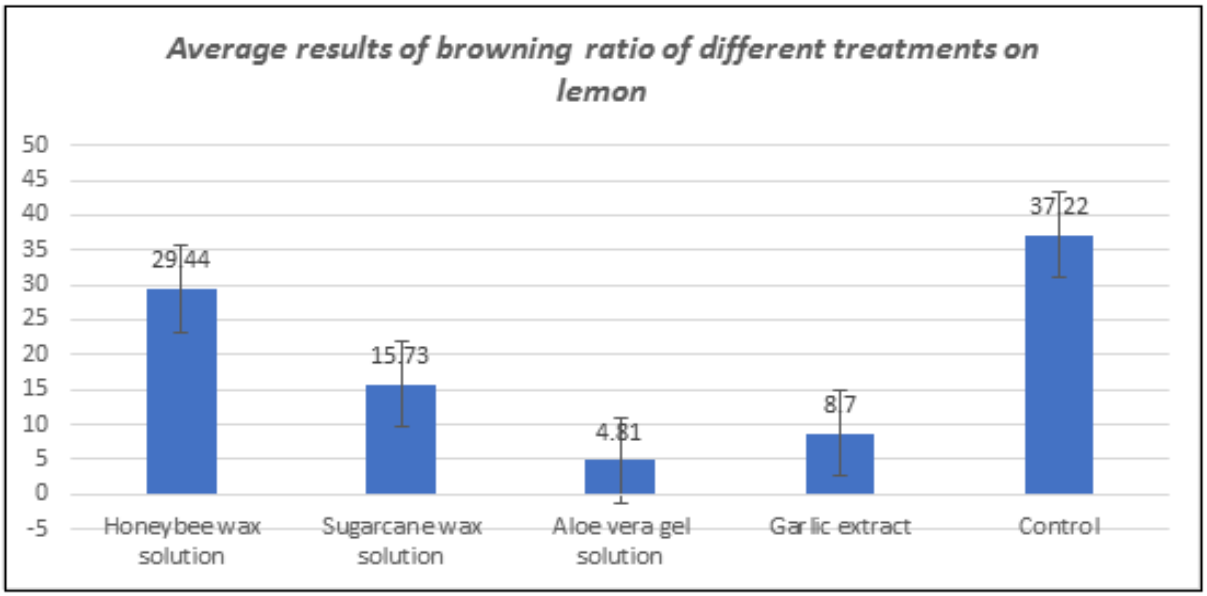

Fig. 3. Scores of visual aspects on average results of browning after 0, 2, 4, 6, 8 and 10 days of storage at room temperature of control and coated lemons with (30%) Garlic extract solution, (15%) Honeybee wax solution, (15%) aloe vera gel solution, (15%) sugarcane wax solution at ambient condition (26 ± 7 °C and 73± 9% RH).

The regression data showed that overall, there was negative correlation between pH of lemons and no. of days (Table 9). The p=0.0183 depicted that the data is significantly different for all treatments and control condition (Table 10).

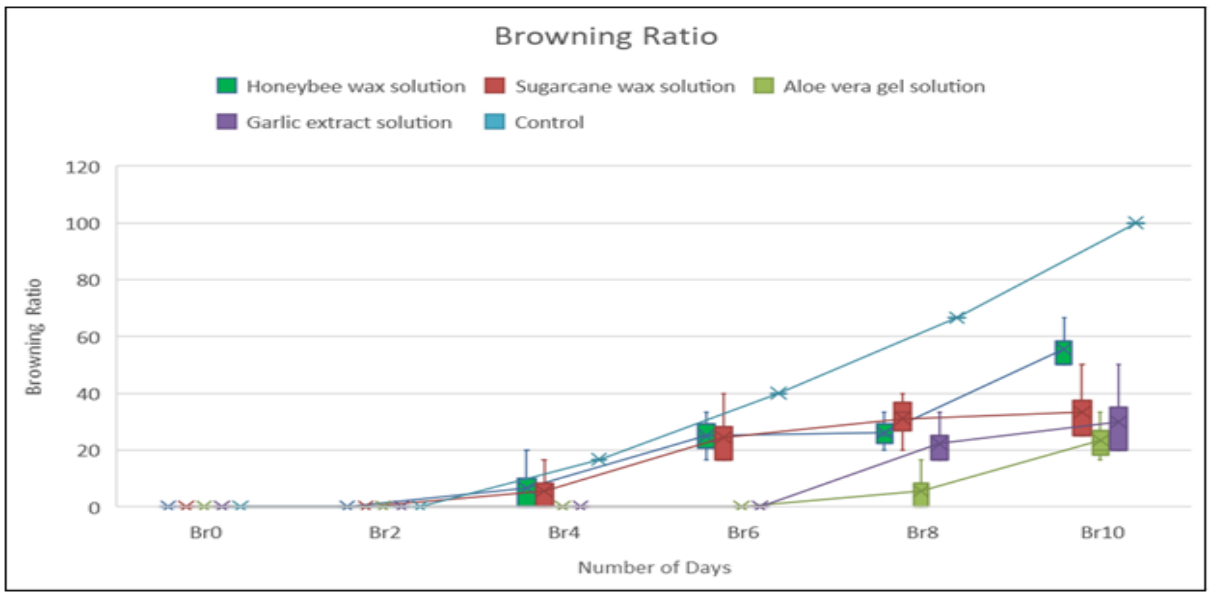

Fig. 4. Scores of visual aspects on browning after 0, 2, 4, 6, 8 and 10 days of storage at room temperature of control and coated lemons with (30%) Garlic extract solution, (15%) Honeybee wax solution, (15%) aloe vera gel solution, (15%) sugarcane wax solution at ambient condition (26 ± 7 °C and 73± 9% RH).

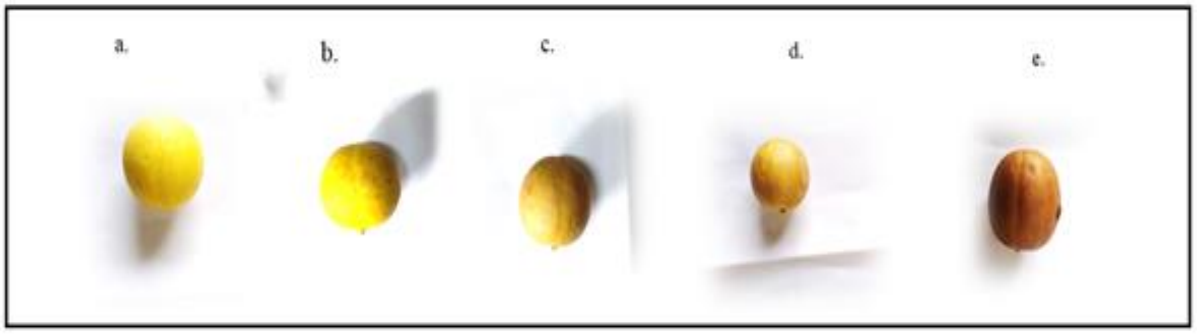

Fig. 5. Browning ratio of lemons with passage of time.

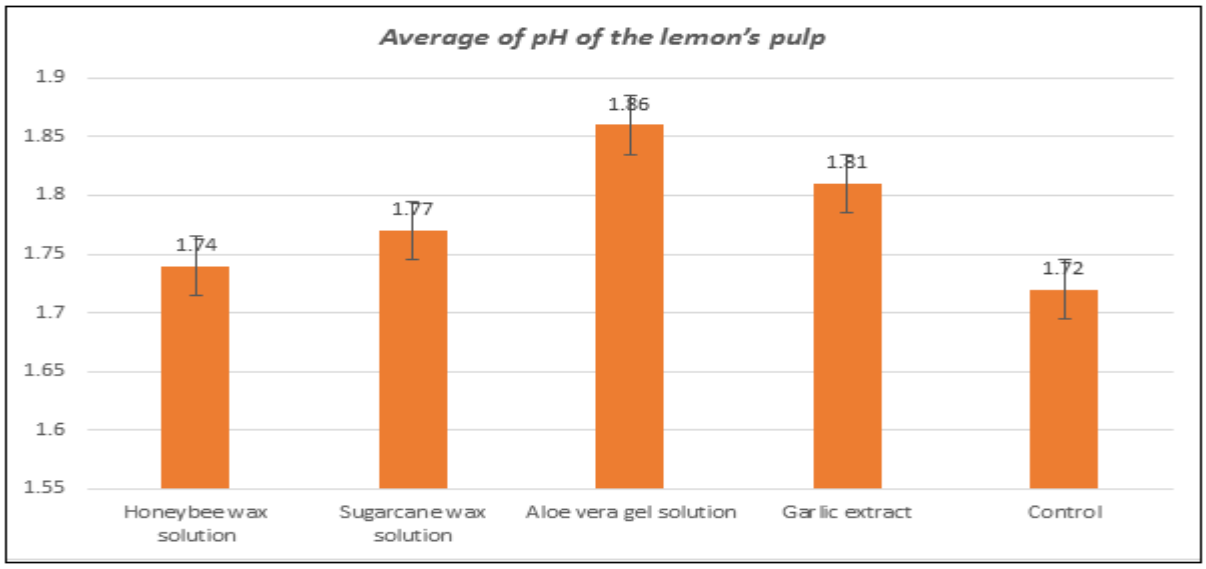

Fig. 6. Scores of visual aspects on average pH of lemon pulp after 0, 2, 4, 6, 8 and 10 days of storage at room temperature of control and coated lemons with (30%) Garlic extract solution, (15%) Honeybee wax solution, (15%) aloe vera gel solution, (15%) sugarcane wax solution at ambient condition (26 ± 7 °C and 73± 9% RH).

Thus all results predicts that pH decreases least in aloe vera gel treated lemons while the maximum decrease in pH occurs in the control condition. Hence it is proved that aloe vera gel along with its antimicrobial and antifungal effect has the potential to retain the pH of the fruits which is an indicator of retaining food quality and flavor.

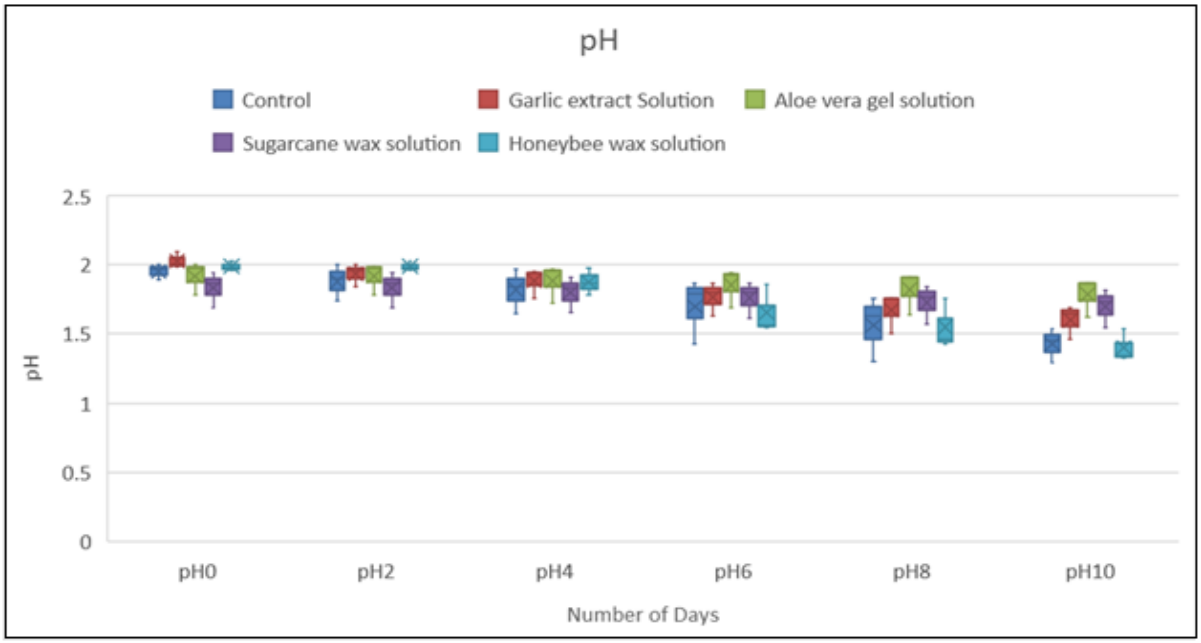

Fig. 7. Scores of visual aspects on pH of lemon pulp after 0, 2, 4, 6, 8 and 10 days of storage at room temperature of control and coated lemons with (30%) Garlic extract solution, (15%) Honeybee wax solution, (15%) aloe vera gel solution, (15%) sugarcane wax solution at ambient condition (26 ± 7 °C and 73± 9% RH).

Overall, all applied treatments showed good results. Control indicated the least outcomes while the utilization of 15% aloe vera gel demonstrated excellent results in reducing percentage moisture loss.

Conclusion

Compared with untreated lemons, *Aloe vera* gel solutions i.e., 15% have ended up being the best antifungal and antimicrobial agent. It can diminish water loss and moderate moisture and possibly be termed as an enemy of the anti-browning agent. It facilitates controlling maturation development and senescence of organic product in post-harvest storage conditions. Following aloe vera gel solutions, Garlic extract solutions have indicated prominent aftereffects of preserving food without multiplication of microbes and fungi. Likewise, it slowed down the maturing phase of the lemon organic product. While the sugarcane wax solutions and honeybee wax solutions provided poor outcomes as the lots were diseases and damaged but better than control.

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