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Research Article

Effects of Calyx Retention and Organic Extracts on Shelf Life and Quality of Strawberry (*Fragaria × ananassa* Duch.)

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ABSTRACT

Strawberry is a very nutritious but highly perishable fruit, which requires appropriate technology to maintain postharvest quality. An experiment was conducted to develop a safe technology for extension of shelf life and quality of strawberry using calyx retention and organic extracts. The experiment consisted of two-factor: Factor A: Calyx retention, viz. without calyx and peduncle (P_0), calyx with peduncle (P_1), and calyx without peduncle (P_2), and Factor B: Organic extracts viz., control (T_0), garlic extract @ 1:1 (T_1), aloe vera extract @ 1% (T_2), and chitosan coating 0.2% (T_3). The experiment was laid out in completely randomized design with three replications. Results revealed that combined treatment of calyx with peduncle and edible garlic extracts showed best external appearance among the treatments. The maximum weight loss (26.51%) was recorded in calyx with peduncle plus control, while the minimum weight loss (16.41%) was found from calyx with peduncle plus garlic extract. The maximum TSS content (8.69%), disease incidence (55.54%) and severity (33.38%) were recorded in without calyx and peduncle plus control, while the minimum TSS content (6.87%), disease incidence (9.26%) and severity (5.40%) were observed in calyx with peduncle plus garlic extract. The longest shelf life (6.67 days) was obtained from calyx with peduncle plus garlic extracts, while the shortest shelf life was found from without calyx and peduncle plus control. Therefore, combined treatment of calyx with peduncle plus garlic extract was found to be better in respect of reducing postharvest diseases, shelf life prolongation and quality retention of strawberry.

Introduction

Strawberry (*Fragaria × ananassa* Duch.) is an important table fruit of millions of people throughout the world. It is a perennial, stoloniferous herb belonging to the family Rosaceae. Strawberry has traditionally been a popular delicious fruit for its flavor, taste, fresh use, freezing and processing (Sharma, 2002). It is usually eaten raw or used in preparing ice creams, jams, jellies, pickles, chocolates, biscuits, cakes and milk shakes. As compared to other berry fruits, strawberries contain a higher percentage of vitamin C, phenolics and flavonoids (Hakkine et al., 2000).

Strawberry is a fruit of unique taste with a rich source of high levels of vitamin C and vitamin E, beta-carotene, anti-oxidant and phenolic compound such as anthocyanins, which can exert a beneficial effect on health (Van De Velde et al., 2013) which are readily available and easily absorbed by human body. Being the most important phenolic compound, anthocyanin causes the red color of strawberry (da Silva et al., 2007). Strawberry is rich in varieties of life saving proteins as well as beta-carotene (precursor of vitamin A), vitamin C, vitamin E, alagic acid, folic acid, kumaric acid, janthomycin and phytostebol (Anonymous, 2008). Some of these nutrients can prevent cancer and AIDS.

Strawberry fruit are particularly perishable, especially after harvest, when even if they are apparently healthy at the time of harvest, they can undergo spoilage of strawberry fruit during storage and shelf life are the development of rots that are caused by a range of fungi. Different postharvest methods can control the devastating disease and improve the situation. Therefore, this includes the main strawberry pathogens, *Botrytis cinerea*, which is the causal agent of gray mold, and the many other pathogens that can cause postharvest spoilage, including *Rhizopus stolonifera*,

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Mucor spp*, Colletotrichum* spp. Many preservation methods have been used to extend the shelf life and improve the quality of strawberry such as refrigeration, synthetic chemical fungicides, osmotic treatments, hypobaric treatments, heat treatment, controlled atmospheres and gamma irradiation (Bhat and Stamminger, 2015). Some environmental friendly plant extracts have been shown to have great potential as an alternative to synthetic fungicide such as Garlic, Onion. Ginger, Neem, Aloe Vera etc. (Janisiewicz et al., 2002; Rashid and Rahman, 2020). Edible coatings such as Aloe Vera, ethanoic extracts of garlic cloves, chitosan, etc. have been used as novel promising approach for the preservation and extending shelf life of fruits (Gol et al., 2013). In the last several years, edible coatings have been widely studied for the preservation of fruits and vegetables (Rashid et al., 2019). Edible coating with semipermeable films might extend the postharvest life of strawberry through a reduction of moisture, gas exchange, respiration and oxidative reaction rates (Estiaque et al., 2021). Chitosan treatment significantly reduced water loss and delayed the qualitative changes in color, titratable acidity and ascorbic acid content in dose- and cultivar-dependent manners (Petriccione et al., 2015; Rashid and Rahman, 2020).

Chitosan is the name used for low acetyl substituted forms of chitin with a typical degree of acetylation of less than 35% (Kumar, 2000). Chitosan is composed primarily of glucosamine, 2-amino-2-deoxy-13-D-glucose (Shahidi et al., 1999). It is high molecular weight cationic polysaccharide and tasteless fiber (Ghaouth et al., 1992). It is non-toxic, biodegradable, bio-functional and biocompatible. Chitosan has strong antimicrobial and antifungal activities that could effectively control fruit decay (Aider, 2010; Romanazzi et al., 2017). It could easily form coating on fruits and vegetable; and the respiration rate of fruits and vegetables reduce by adjusting the permeability of carbon dioxide and oxygen (Elsabee et al., 2013).

Occasionally, the law enforcement agencies discover that a large proportion of fruits available in the market are being contaminated with formalin (Ashfaq, 2013), which is a big threat to human health in this country as increasing number of food items such as fruits, fishes and vegetables have been found contaminated with this hazardous chemical (Haque, 2014). Development of a natural and safe technology for extending shelf life of these perishable fruits and vegetables is currently needed. The present study was, therefore, undertaken to develop a safe technology for extension of shelf life and quality retention of strawberry by calyx retention and organic extracts.

Materials and Methods

Experimental location

The experiment was conducted to study the effect of calyx retention and organic extracts on shelf life and quality of strawberry at the Laboratory of the Department of Horticulture, Bangladesh Agricultural University (BAU), Mymensingh during the period from February to March 2020.

Experimental materials

Light red colored strawberry fruits *cv.* RU-1 (Festival) was collected from the Akafuji nursery, University of Rajshahi, Rajshahi, Bangladesh. Strawberry fruits were then taken to the Laboratory of the Department of Horticulture, BAU. Collected strawberry fruits were uniform in shape, size, weight (average 10-12 g) and without visible imperfections or quality defects.

Experimental treatments and design

The experiment consisted of two-factors: Factor A: Calyx retention, viz. without calyx and peduncle (P_0), calyx with peduncle (P_1), and calyx without peduncle (P_2), and Factor B: Organic extracts viz., control (T_0), garlic extract @ 1:1 (T_1), aloe vera extract @ 1% (T_2), and chitosan coating 0.2% (T_3). The experiment was laid out in completely randomized design with three replications. 540 strawberry fruits were collected for conducting the experiment from which 10 fruits under each treatment were used as non-destructive sample for external colour, weight loss, disease incidence and severity, and shelf life studies, and 5 fruits under each treatment were used as destructive sample for chemical analysis.

Application of the natural postharvest treatments

The postharvest treatments were sequentially applied to the selected strawberry fruits, which were dipped in each natural edible coating solutions for 2-3 minutes, air-dried and then kept under ambient temperature (25 ± 1°C) using plastic punnets. For control, ten fruits under each treatment were selected randomly from a strawberry fruit lots, washed with distilled water, air-dried. For control (T_0), fruits were selected randomly from a lot of strawberry and the fruits were kept on brown and white paper of the laboratory table at room condition arranging at random by replication. For garlic treatment (T_1), initially stock garlic extract (1 kg garlic cloves and 1 L water) was prepared by crushing the fresh cloves in distilled water using a blender through straining and then cheesed. The stock extract was used to prepare treatment of 1:1 concentration. For aloe vera coating (T_2), the selected fruits were dipped in 1% aloe vera solution for 2-3 minutes. Aloe vera gel was extracted from fresh aloe vera leaves as described by Sharmin et al. (2015). For chitosan coating (T_3), the selected strawberry fruits were dipped at 0.2% chitosan

solution for 2-3 minutes and air-dried. Chitosan solution (0.2%) was prepared by dissolving 0.2 g of chitosan in 100 mL of distilled water. The mixture was heated with continuous stirring for proper dissolution of chitosan. The final pH of the solution was adjusted to 5.6 with 2 N NaOH and made up to 100 mL with distilled water. After application of all the treatments, fruits were wrapped with the plastic punnest and kept at ambient temperature (25 ± 1°C) and all changes of the fruits were monitored, every day started from 0 day to last days of storage.

Parameters studied

Weight loss

Weight loss of strawberry was measured by weighing the individual fruits one-day interval by using a top pan electric balance. Ten fruits per treatment were taken for this purpose and same fruits were used until the end of the experiment. The percentage of weight loss was calculated at one-day interval during storage by using the following formula:

$$\% \text{ Weight loss} = \frac{W1 - W2}{W1} \times 100$$

Where,

W_1 = Initial weight of fruit (0 days)

W_2 = Fruits weight at various storage periods (0, 1, 2, 3, and 4 days)

Fruit firmness

Strawberry firmness is affected by fruit size, stage of maturity (Schmitz and Lenz, 1985). Firmness of strawberry fruit was measured by Fruit Penetrometer (Model PX-145, Panomex Inc.). The Fruit Penetrometer accurately measures fruit hardness by measuring the force required to push a plunger tip (of a certain size) into strawberry fruit. The instrument was equipped with a 3.5 mm pressure head that had 10 mm insertion depth of pressure head.

Fruit pH

The pH of fruit juice was measured by using a Portable pH Meter (Model pHS-1701, Shanghai, China), which was standardized with the help of a buffer solution as described by Ranganna (1994).

Total soluble solids (TSS)

The total soluble solids content (TSS, Brix) was determined for the flesh juice using a digital refractometer. The remaining juice from pH determination was used to measure the TSS of the fruit juice. Before measurement, the refractometer was calibrated with distilled water to give a zero reading. One or two drops of the filtrate fruit juice were placed on the prism of the refractometer to obtain percentage TSS reading. The reading was multiplied by dilution factor to obtain an original percentage TSS of the fruit tissues. Since differences in sample temperature could affect the TSS measurement, temperature corrections were made by using the methods described by Ranganna (1994).

Disease incidence (percentage of infected fruits)

Disease incidence resulting from natural infection was assessed as time to when 10% of the surface area of each fruits was affected (Terry and Joyce, 2004). Ten fruits for each treatment were critically examined every day for the appearance of the disease symptoms and the incidence was recorded. The first count was made at the 1st day of storage. The disease development was identified by the visual quality, which was observed on the scale of 1 to 5 (one = very bad, two = bad, three = good, marketable, four = very good, and five = excellent) (Islam et al., 2017). Three fungal diseases like Grey mould, Rhizopus soft rot and Leather rot were identified by observing the typical symptoms of those fungal diseases, which were caused by *Botrytis cinerea*, *Rhizopus stolonifer* and *Phytophthora cactorum*, respectively (Mass, 1998). Number of fungus-contaminated strawberry was counted and the disease incidence was calculated as follow:

$$\% \text{ Disease incidence} = \frac{\text{Number of infected fruits}}{\text{Total number of fruits assessed}} \times 100$$

Disease severity (percentage of skin-infected fruits by fungal diseases)

Disease severity represents the percent diseased portion of the infested fruit. In order to measure disease severity level, the strawberry fruits were critically observed and the percent skin infected fruits was recorded every day starting from the 1st day of storage up to the last day. All the infected fruits were taken to determine the percent fruit area infected and carefully evaluated. This evaluation was determined by centimeter scale by calculating the mean values regarding the infected fruit areas.

Titratable acidity (TA) and ascorbic acid (Vitamin C) contents

Using the filtrate prepared to determine TSS, titratable acidity of strawberry juice was determined by titration against 0.1 N sodium hydroxide. Ascorbic acid (vitamin C) was measured by 2, 6-dichlorophenol-indophenol titration as described by Ranganna (1994).

Shelf life

Shelf life of fruits means the days required for fully ripe as to retaining optimum marketing and eating qualities. Shelf life of strawberry fruits as influenced by variety

and different postharvest storage treatments was calculated by counting the days required to ripe fully as to retaining, optimum marketing and eating quality. In order to determine the shelf life, ten fruits were taken for each treatment and then the treated fruits were kept under ambient temperature (25 ± 1° C). Shelf life was measured according to visual quality (≥3; good, marketable) and determinants such as mold growth, decay, shriveling, smoothness, shininess, and homogeneity (Islam et al., 2017).

Statistical analysis

The collected data on various parameters were analyzed statistically using MSTAT computer programmed. The means for all the treatments were calculated and analysis of variance (ANOVA) was performed by F-test. The mean difference between a pair of treatments was tested by least significant difference (LSD) at 5 and 1% levels of probability (Gomez and Gomez, 1984).

Results and Discussion

Weight loss

All strawberries showed a gradual loss of weight during storage and weight loss was significantly varied due to calyx retention (Fig. 1). The highest weight loss (24.54%) was found from 4 days after storage in P_0 (without calyx and peduncle) followed by (22.43%) P_2 (calyx without peduncle) whereas the lowest data (22.12%) was found from P_1 (calyx with peduncle) in 4 days of after storage (Fig. 1). In case of organic extracts, effects on weight loss of strawberry were varied significantly (Figure 2). The highest weight loss (24.56%) was found from 4 days after storage in T_3 (chitosan coating) followed by 23.36% in T_2 (Aloe vera) whereas the lowest data (20.87%) was found from T_1 (garlic) (Fig. 2). The loss of weight in fresh fruit primarily reflects the respiration rate and moisture evaporation between the fruit tissue and surrounding air, which are influenced by postharvest treatment and storage temperature (Munoz et al. 2006). Garlic extract shows better results due to contain an array of substances with beneficial health-related biological properties recently reported that garlic extracts displayed a growth-inhibiting activity against fungus multiplying in the oral-gastrointestinal tract of humans. This document indicated also that fresh garlic extracts had a greater efficacy than dehydrated extracts (Agarwal, 1996).

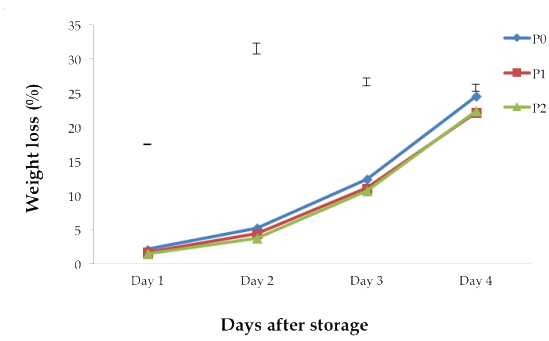

Figure 1. Main effect of calyx on percent weight loss at different days after storage of strawberry. The vertical bars represent LSD at 1% level of probability. P_0 = without calyx and peduncle, P_1 = Calyx with peduncle.

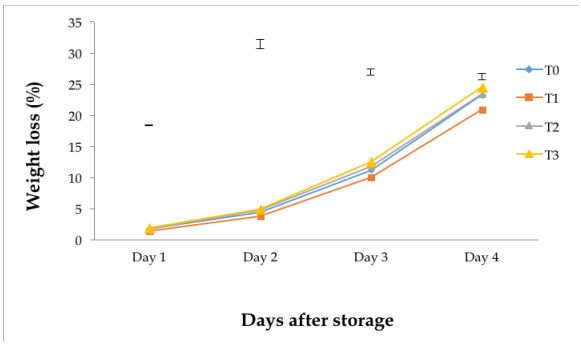

Figure 2. Main effect of organic extracts on percent weight loss at different days after storage of strawberry. The vertical bars represent LSD at 1% level of probability. T_0 = Control, T_1 = Garlic extract, T_2 = Aloe vera extract, T_3 = Chitosan coating.

Combined effects of calyx and organic extracts had significant influence on weight loss of strawberry (Table 1). The maximum weight loss (26.51%) was noticed from P_1T_0 (calyx with peduncle plus control) at 4 days after storage, whereas second highest data (25.82%) was recorded from P_0T_3 (without calyx and peduncle treated with chitosan) and the lowest data (16.41%) was recorded from P_1T_1 (calyx with peduncle treated with garlic extract) (Table 1). Strawberry fruits are highly susceptible to a rapid loss of water due to the extremely thin skins of these fruits. These results are consistent with those of previous studies demonstrating that chitosan coating acts as a semipermeable barrier against oxygen, carbon dioxide and moisture, thereby reducing respiration and water loss and counteracting the dehydration and shrinkage of the fruit (Ghaouth et al., 1991; Velickova et al., 2013, Petriccione et al., 2015). Respiration processes and is a major cause of quality deterioration (Hernández et al., 2006).

Table 1. Combined effects of calyx and organic extracts on percent weight loss and fruit firmness at different days after storage of strawberry

Treatment combination	Weight loss (%) at different DAS				Fruit firmness (%) at different DAS			
	1	2	3	4	1	2	3	4
P_0T_0	1.68	3.95	10.30	21.97	4.30	3.89	3.21	3.09
P_0T_1	1.98	5.35	12.55	24.71	4.28	4.00	3.75	3.36
P_0T_2	2.26	5.90	13.54	25.67	4.62	4.33	3.96	3.86
P_0T_3	2.47	5.56	13.12	25.82	4.40	3.92	3.51	3.39
P_1T_0	2.38	5.79	13.22	26.51	4.39	4.11	3.73	3.54
P_1T_1	1.14	2.70	7.52	16.41	5.42	4.85	4.41	4.20
P_1T_2	1.33	3.97	10.37	21.33	4.62	4.44	4.05	3.91
P_1T_3	2.00	5.27	13.14	24.23	4.52	3.70	3.31	3.07
P_2T_0	1.43	3.65	10.20	21.50	4.59	4.15	3.78	3.61
P_2T_1	1.21	3.34	9.95	21.49	4.59	4.16	3.69	3.51
P_2T_2	1.72	4.26	11.28	23.08	4.52	3.99	3.55	3.29
P_2T_3	1.39	3.94	11.35	23.64	4.77	4.24	3.80	3.54
$LSD_{0.05}$	0.09	1.39	0.93	0.87	0.12	0.09	0.12	0.15
$LSD_{0.01}$	013	1.88	1.27	1.18	0.16	0.13	0.16	0.20
Level of significance	**	**	**	**	**	**	**	*

**, * = Significant at 1 and 5% levels of probability, respectively. P_0 = without calyx and peduncle, P_1 = Calyx with peduncle, P_2 = Calyx without peduncle. T_0 = Control, T_1 = Garlic extract, T_2 = Aloe vera extract, T_3 = Chitosan coating.

Fruit firmness

Firmness is an important physical parameter used to assess the quality of fruits during ripeness, storage and distribution (Pasquariello *et al.,* 2013). Fruit firmness of strawberry was varied significantly due to calyx retention (Fig. 3). The highest fruits firmness (3.68) was recorded from 4 days after storage in P_1 (calyx with peduncle) followed by 3.49 in P_2 (calyx without peduncle), whereas lowest data (3.43) was found from P_0 (without calyx and peduncle) (Figure 3). In case of organic extracts, effects on fruit firmness of strawberry were varied significantly (Fig. 4). The highest fruit firmness (3.69) was found from 4 days after storage in T_1 and T_2 (garlic and aloe vera extracts), whereas the lowest data (3.34) was found from T_3 (chitosan) (Figure 4). Statistically significant variation was observed between the calyx retention and organic extracts treatments in reference to strawberry fruit firmness (Table 1). Fruit firmness was decreased gradually with the storage period irrespective of different calyx retention and organic extracts treatments at 4 DAS. The highest fruits firmness (4.20) was noticed from P_1T_1 (calyx with peduncle plus garlic extracts), whereas the lowest data (3.07) was recorded from P_1T_3 (calyx with peduncle plus chitosan) (Table 1). Firmness is an essential factor that influences the consumer acceptability of fresh fruit (Wang and Gao, 2013). Decreasing firmness may be due to pectin, which is the most abundant polymer in the middle lamella, and it regulates intercellular adhesion, but primary fruit cell walls are also rich in polyuronides, accounting for up to 60% of cell wall mass in many fruits (Willats et al., 2001).

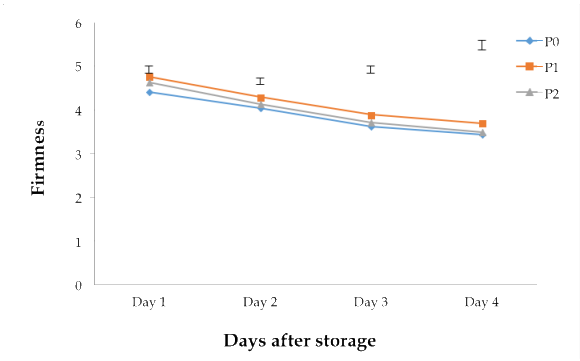

Figure 3. Main effect of calyx on fruit firmness at different days after storage of strawberry. The bars represent LSD at 1% level of significance. P_0 = without calyx and peduncle, P_1 = Calyx with peduncle, and P_2 = Calyx without peduncle.

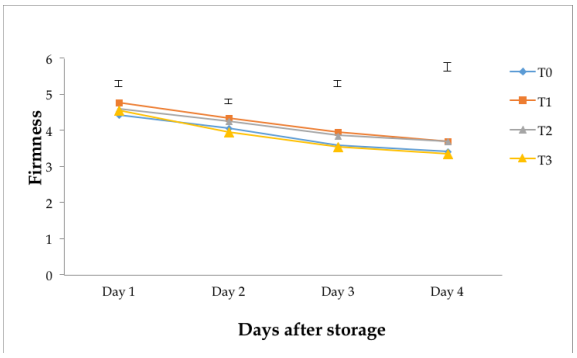

Figure 4. Main effect of organic extracts on fruit firmness at different days after storage of strawberry. The vertical bars represent LSD at 1% level of probability. T_0 = Control, T_1 = Garlic extract, T_2 = Aloe vera extract, T_3 = Chitosan coating.

Fruit pH

The effect of different postharvest treatments in respect of fruit pH content was statistically significant at different days of storage (Fig. 5). In case of calyx retention, effects on pH changes of strawberry fruits were varied significantly (Fig. 3). The highest pH change (6.46) was found from 4 days after storage in P_2 (calyx without peduncle) followed by (6.45) P_0 (without calyx peduncle), whereas the lowest data (6.19) was obtained from P_1 (calyx with peduncle) (Fig. 5). In case of organic extracts, pH changes were found to be faster (6.68) in fruits without any treatments (control) and pH changes were found to be slower (6.05) in fruits of the treatment with T_1 (garlic extracts) after 4 day of storage (Fig. 6). The pH content of fruit varied among the fruits kept under different postharvest treatments. Results showed that the pH of strawberries increased during storage (Table 2). At 4 DAS, the highest fruit pH (6.90) was noticed from P_0T_0 (without calyx peduncle and without any organic extracts) where the second highest data (6.63) was recorded from P_2T_0 (calyx without peduncle and untreated fruits) and the lowest data (5.52) was recorded from P_1T_1 (calyx with peduncle plus garlic extracts). The result was still above the 57 average reported values for ripe strawberry of 3.3 (Elena et al., 2013). This could be attributed, the increase in pH of fruit during ripening, corresponding decrease in acidity caused by degradation of acids during ripening and senescence (Yüksel et al., 2009).

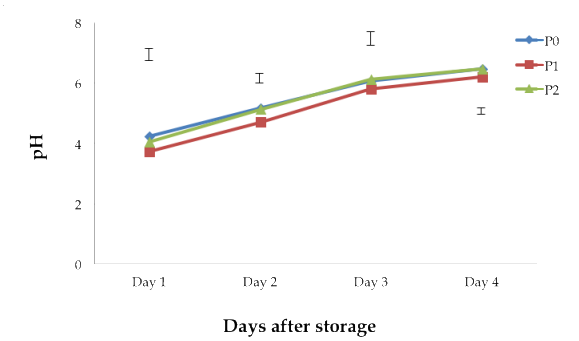

Figure 5. Main effect of calyx on pH at different days after storage of strawberry. The vertical bars represent LSD at 1% level of probability. P_0 = without calyx and peduncle, P_1 = Calyx with peduncle and P_2 = Calyx without peduncle.

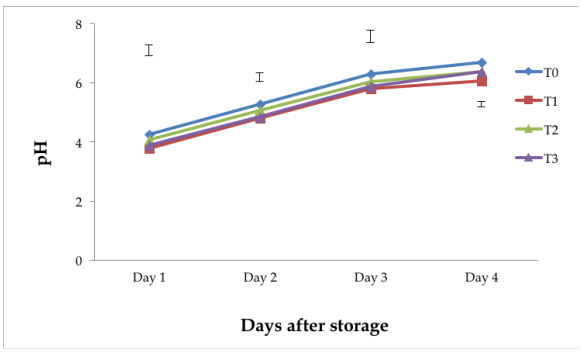

Figure 6. Main effect of organic extracts on pH at different days after storage of strawberry. The vertical bars represent LSD at 1% level of probability. T_0 = Control, T_1 = Garlic extract, T_2 = Aloe Vera extract and T_3 = Chitosan coating.

Table 2. Combined effects of calyx and organic extracts on fruit p^H and total soluble solids (TSS) at different days after storage (DAS) of strawberry

Treatment combination	Fruit pH at different DAS				TSS (%brix) at different DAS			
	1	2	3	4	1	2	3	4
P_0T_0	4.52	5.58	6.37	6.90	5.30	6.17	7.45	8.69
P_0T_1	4.05	5.21	6.05	6.27	4.63	5.37	6.37	7.92
P_0T_2	4.43	5.10	6.07	6.30	4.87	5.80	6.73	7.96
P_0T_3	3.93	4.73	5.70	6.33	4.90	5.83	6.77	7.57
P_1T_0	3.80	4.97	6.28	6.51	4.93	5.94	6.84	8.16
P_1T_1	3.56	4.22	5.29	5.52	3.90	4.90	6.13	6.87
P_1T_2	3.93	5.13	5.91	6.41	4.85	5.73	6.57	7.87
P_1T_3	3.60	4.43	5.73	6.30	4.87	5.67	6.60	7.70
P_2T_0	4.43	5.23	6.23	6.63	5.01	5.98	6.86	8.27
P_2T_1	3.73	4.93	6.00	6.37	4.83	5.51	6.40	7.60
P_2T_2	3.86	4.97	6.07	6.41	4.86	5.68	6.74	7.84
P_2T_3	4.10	5.33	6.17	6.43	4.89	5.69	6.71	7.97
$LSD_{0.05}$	0.28	0.21	0.31	0.13	0.14	0.12	0.27	0.14
$LSD_{0.01}$	0.38	0.29	0.42	0.18	0.19	0.16	0.36	0.19
Level of significance	**	**	**	**	**	**	*	**

**, * = Significant at 1 and 5% levels of probability, respectively. P_0 = without calyx and peduncle, P_1 = Calyx with peduncle, P_2 = Calyx without peduncle. T_0 = Control, T_1 = Garlic extract, T_2 = Aloe vera extract, T_3 = Chitosan coating.

Total soluble solids (TSS)

The postharvest treatments used in the present investigation showed statistically significant variation in respect of total soluble solids (TSS) content at all days of storage (Fig. 7). In case of calyx, the maximum TSS content (8.04%) was found from P_0 (without calyx peduncle), whereas the minimum TSS content (7.65%) was found from P_1 (calyx with peduncle) after 4 days of storage (Fig. 7). In case of organic extracts, effects on TSS of strawberry were varied significantly (Figure 8). The highest TSS (8.37) was found from 4 days after storage in T_0 (control) followed by 7.89 from T_2 (Aloe vera), whereas the lowest data (7.46) was recorded from T_1 (garlic) (Fig. 6). The fruits during storage loss stability of cell wall due to collapse of pectin as a result the TSS increased and firmness decreased (Safizadeh, 2013). The aqueous extract of garlic delay the process of ripening, retain firmness for longer time and boost resistance against disorders of storage (Kamel, 2014). TSS content in fruit juice gradually increased during storage period irrespective of all treatments, which was similar to the investigation of Panda et al. (2016) and Petriccione et al. (2015) where the authors reported that uncoated and no packaging fruits exhibited significantly ($p < 0.05$) higher TSS compared to all other edible-coated fruits.

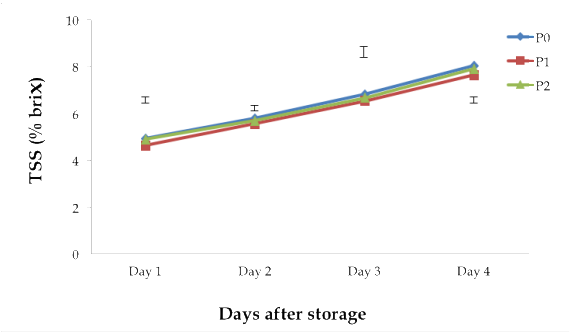

Figure 7. Main effect of calyx on total soluble solids (TSS) at different days after storage of strawberry. The vertical bars represent LSD at 1% level of probability. P_0 = without calyx and peduncle, P_1 = Calyx with peduncle and P_2 = Calyx without peduncle.

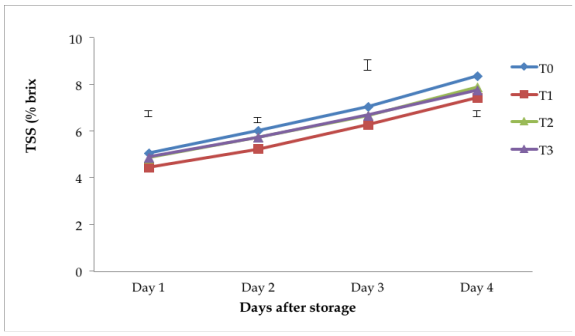

Figure 8. Main effect of organic extracts on total soluble solids (TSS) at different days after storage of strawberry. The vertical bars represent LSD at 1% level of probability. T_0 = Control, T_1 = Garlic extract, T_2 = Aloe vera extract and T_3 = Chitosan coating.

The TSS of strawberry fruits under combined effects of different calyx retention and organic extract treatments exhibited significant variation (Table 2). At 4 DAS, the maximum TSS (8.69) was noticed from P_0T_0 (without calyx peduncle plus control) whereas lowest data (6.87) was recorded from P_1T_1 (Table 2). At the end of cold storage, uncoated "Jonica" and "Sabrina" fruits exhibited significantly ($p < 0.05$) higher TSS compared to all other chitosan-coated fruits. These results are consistent with those of other studies concerning the effects of chitosan-coated treatment on different commodities, such as mango, guava, banana, papaya, guava and sweet cherry (Kittur et al., 2001; Ali et al., 2011; Hong et al., 2012; Petriccione et al., 2015). The low increase in TSS values for the chitosan-coated fruits, from the three strawberry cultivars. Strawberry might reflect changes in the internal atmosphere of the fruit, with a reduction in the O_2 level and an increase in the CO_2 level, which reduce the respiration rate and metabolic activity, such as the conversion of sugars into CO_2 and H_2O (Ghasemnezhad et al., 2011).

Disease incidence and severity

Overall disease incidence and severity of strawberry fruits trended to increase with the progress of storage duration. In case of calyx retention, effects on disease incidence and severity of strawberry were varied significantly (Fig. 9-10). The highest disease incidence (35.41%) and severity (21.22%) were found from 4 days of after storage in P_0 (without calyx and peduncle) and P_2 (calyx without peduncle), respectively, whereas the lowest disease incidence (27.31%) and severity (16.16%) were found from P_1 (calyx with peduncle) (Figure 9-10). In case of organic extracts, effects on disease incidence and severity of strawberry were varied significantly (Fig. 11-12). The highest disease incidence (48.14%) and disease severity (29.88%) were found from 4 days after of storage in T_0 (control), whereas the lowest disease incidence (20.68%) and severity (11.74%) were observed from T_1 (garlic) (Figure 11-12). This might be due to the effects of ethanolic extract and fresh garlic cloves and chitosan coating contain biologically natural fungicide substances which are potentially used for the control of many fungal diseases of fruits (Li and Yu, 2001; Dong et al., 2004; Hernandez-Munoz et al., 2008; Mondal et al., 2011; Nur

Fatima et al., 2018). The combined effect of calyx retention and organic extracts treatments had also significant influence on disease incidence and severity of strawberry (Table 3). At 4 DAS, the maximum disease incidence (55.54%) and severity (31.50%) were noticed from P_1T_0 (without calyx peduncle and without any organic extracts) and P_2T_0 (calyx without peduncle with untreated fruits), respectively, whereas the lowest disease incidence (9.26%) and severity (5.40%) were recorded from P_1T_1 (calyx with peduncle plus garlic extracts) (Table 3). This might be due to the synergistic effects of combined treatments, which could give less detrimental influence to quality attributes of the strawberry fruits.

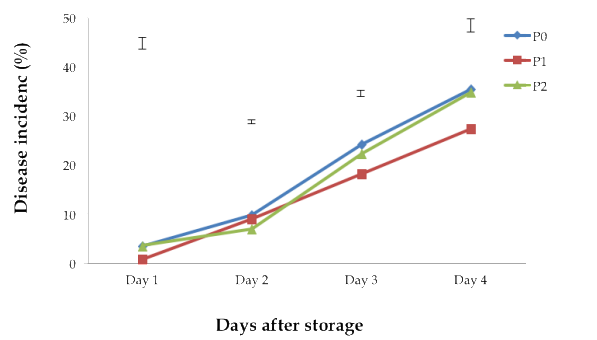

Figure 9. Main effect of calyx on percent disease incidence at different days after storage of strawberry. The vertical bars represent LSD at 1% level of probability. P_0 = without calyx and peduncle, P_1 = Calyx with peduncle, and P_2 = Calyx without peduncle.

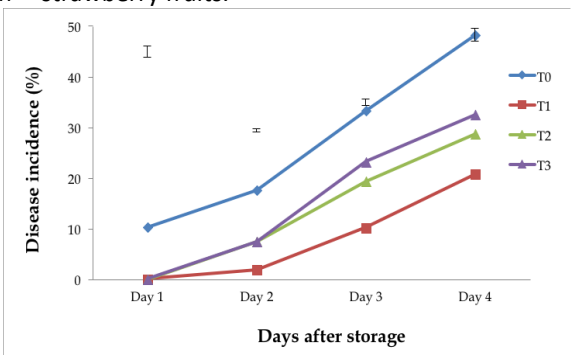

Figure 10. Main effect of organic extracts on percent disease incidence at different days after storage of strawberry at 1% level of significance. T_0 = Control, T_1 = Garlic extract, T_2 = Aloe vera extract and T_3 = Chitosan coating.

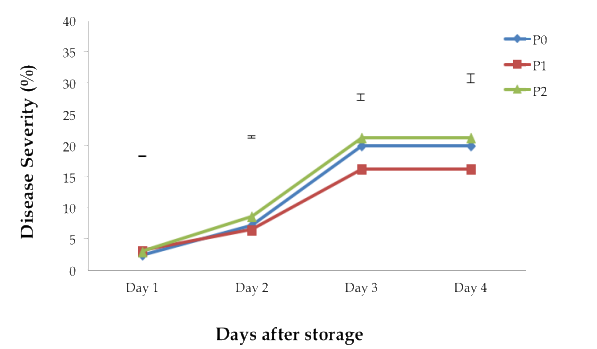

Figure 11. Main effect of calyx on percent disease severity at different days after storage of strawberry. The vertical bars represent LSD at 1% level of probability. P_0 = without calyx and peduncle, P_1 = Calyx with peduncle and P_2 = Calyx without peduncle.

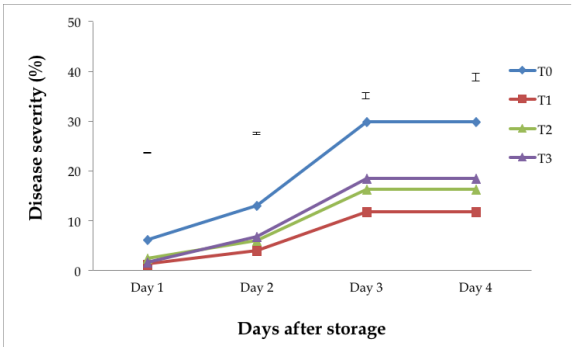

Figure 12. Main effect of organic extracts on percent disease severity at different days after storage of strawberry. The vertical bars represent LSD at 1% level of probability. T_0 = Control, T_1 = Garlic extract, T_2 = Aloe vera extract and T_3 = Chitosan coating.

Table 3. Combined effects of calyx and organic extracts on disease incidence and severity at different days after storage (DAS) of strawberry

Treatment combination	Disease incidence (%) at different DAS				Disease severity (%) at different DAS			
	1	2	3	4	1	2	3	4
P_0T_0	13.89	19.45	44.45	55.54	0.80	6.60	14.40	31.50
P_0T_1	0.00	2.78	11.11	25.00	0.00	1.27	4.57	13.88
P_0T_2	0.00	8.33	16.33	27.78	0.00	1.00	4.17	15.17
P_0T_3	0.00	8.33	25.00	33.33	0.00	0.67	5.71	19.40
P_1T_0	2.78	19.33	27.78	41.67	1.10	6.07	9.56	24.77
P_1T_1	0.00	0.00	5.55	9.26	0.00	0.00	1.27	5.40
P_1T_2	0.00	8.33	19.56	27.78	0.00	4.97	7.29	16.08
P_1T_3	0.00	8.33	19.45	30.55	0.00	1.47	7.84	18.40
P_2T_0	13.90	13.89	27.66	47.22	0.53	5.67	15.04	33.38
P_2T_1	0.00	2.78	13.89	27.78	0.00	2.37	6.20	15.95
P_2T_2	0.00	5.55	22.22	30.55	0.00	1.43	6.51	17.78
P_2T_3	0.00	5.55	25.00	33.33	0.00	2.57	6.76	17.76
$LSD_{0.05}$	4.06	1.17	2.21	4.69	0.09	0.80	2.23	2.91
$LSD_{0.01}$	5.50	1.58	2.99	6.36	0.13	1.09	3.03	3.94
Level of significance	**	**	**	**	**	**	**	**

** = Significant at 1% level of probability. P_0 = without calyx and peduncle, P_1 = Calyx with peduncle, P_2 = Calyx without peduncle. T_0 = Control, T_1 = Garlic extract, T_2 = Aloe vera extract, T_3 = Chitosan coating.

Shelf life

Shelf life is the period from harvesting up to the last edible stage. This is the basic quality of fruits, which helps marketing duration, and it is the most important aspect in loss reduction technology of fruits. The extension of shelf life of fruit has been one of the prime concerns of marketing throughout the record of history (Mondal et al., 2011; Rashid et al., 2015). In case of calyx, effects on shelf life of strawberry were varied significantly (Fig. 13). The longest shelf life (5.25 days) was found from P_1 (calyx with peduncle) and the shortest shelf life (4.75days) was recorded from P_0 (without calyx and peduncle) (Fig. 13). In case of organic extracts, effects on shelf life of strawberry were varied significantly (Fig. 14). The highest shelf life (6.11 days) was obtained from T_1 (garlic extracts), whereas the lowest shelf life (3.33 days) was observed from T_0 (control) (Fig. 14). The combined effect of calyx and organic extracts had significant influence on shelf life of strawberry (Fig. 15). The longest shelf life (6.67 days) was found from P_1T_1 (calyx with peduncle treated with garlic extracts) followed by 6.0 days was obtained from P_2T_1 and lowest shelf life (3.00 days) was recorded from P_0T_0 (without calyx and peduncle with untreated fruits) (Fig. 15). The longest shelf life obtained from garlic extract was possibly due to the reduced rate of physio-chemical changes, reduced weight loss and minimal disease severity (Mondal et al., 2011). The delay in ripening on chitosan coated fruits can occur due to the lower capacity of these fruits in producing ethylene, since this hormone has a stimulation role in the general metabolism, and seems to be implicated in the activation and regulation of some enzymes involved in ripening (Gomez et al., 1999). Plate 1-4 showing photographs of the differences in external appearance of strawberries at various days after storage (DAS) of strawberry under calyx retention and organic extracts treatments.

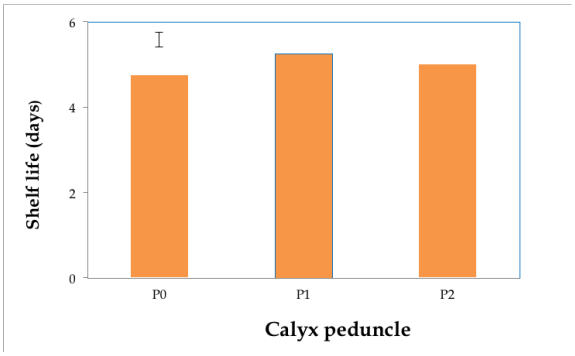

Figure 13. Main effect of calyx on shelf life (days) of strawberry. The vertical bar represents LSD at 1% level of probability. P_0 = without calyx and peduncle, P_1 = Calyx with peduncle and P_2 = Calyx without peduncle.

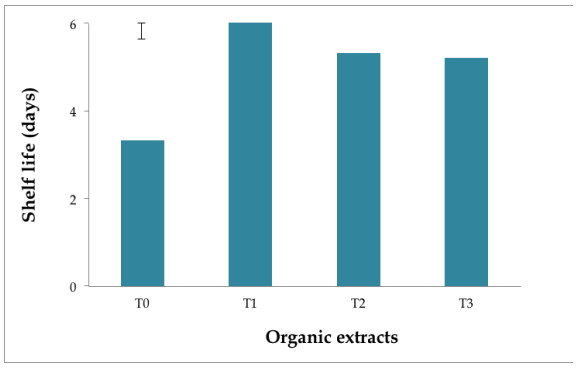

Figure 14. Main effect of organic extracts on shelf life (days) of strawberry. The vertical bar represents LSD at 1% level of probability.. P_0 = Control, T_1 = Garlic extract, T_2 = Aloe vera extract, and T_3 = Chitosan coating.

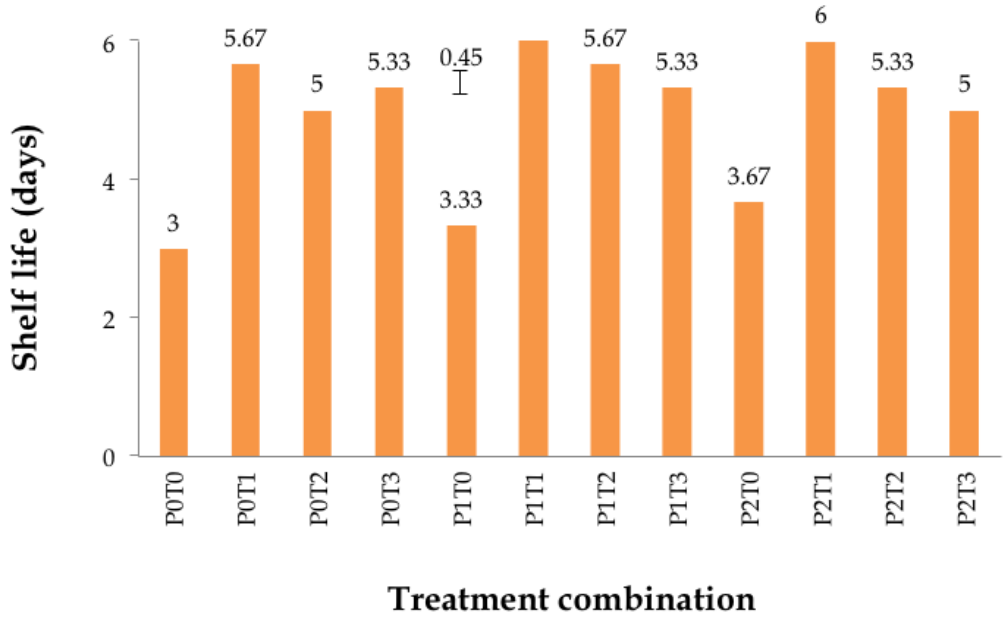

Figure 15. Combined effects of calyx retention and organic extracts on shelf life (days) of strawberry. The vertical bar represents LSD at 1% level of probability. P_0 = without calyx and peduncle, P_1 = Calyx with peduncle, P_2 = Calyx without peduncle. T_0 = Control, T_1 = Garlic extract, T_2 = Aloe vera extract, T_3 = Chitosan coating.

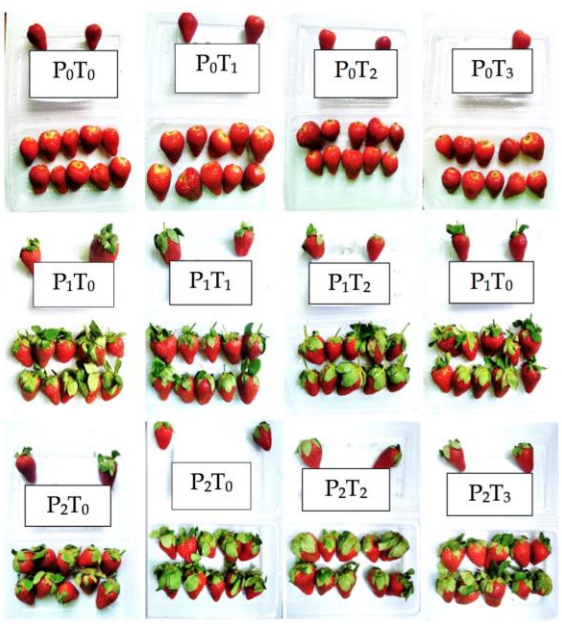

Plate 1. Photographs showing the differences in external appearance of strawberries at 1 day after storage (DAS) under calyx retention and organic extracts treatments.

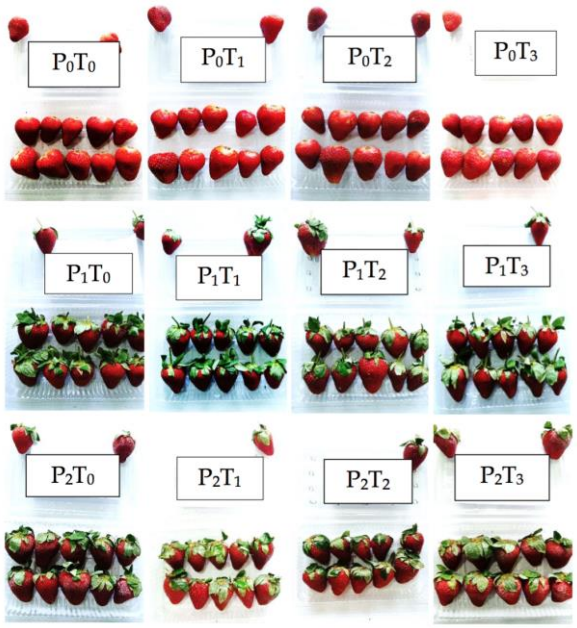

Plate 2. Photographs showing the differences in external appearance of strawberries at 2 day after storage (DAS) under calyx retention and organic extracts treatments.

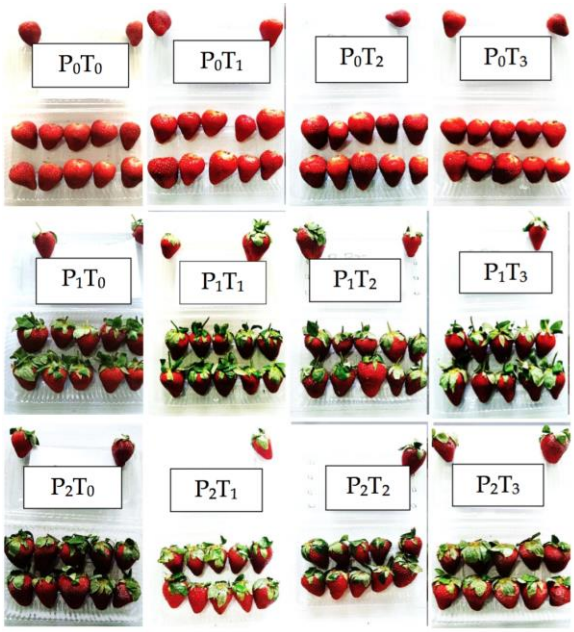

Plate 3. Photographs showing the differences in external appearance of strawberries at 3 day after storage (DAS) under calyx retention and organic extracts treatments.

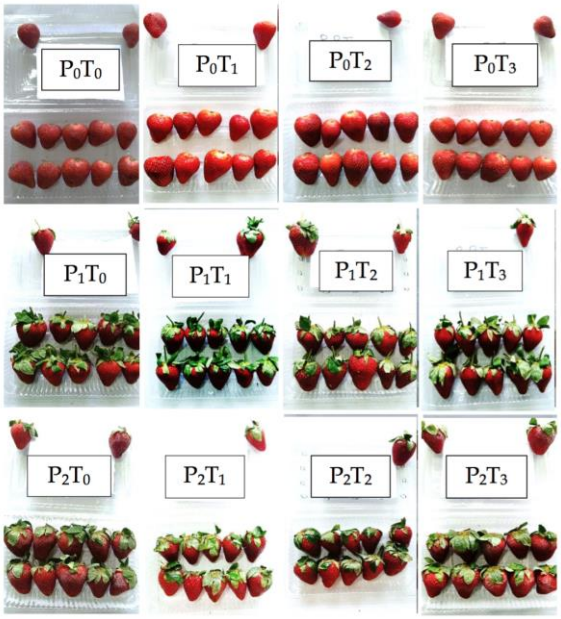

Plate 4. Photographs showing the differences in external appearance of strawberries at 4 day after storage (DAS) under calyx retention and organic extracts treatments.

Conclusion

The present investigation was designed to evaluate the effects of calyx retention and organic extracts on shelf life and quality of strawberry. Rapid quality deterioration is a major problem in strawberry transport and marketing and since refrigerator is not available in all household, especially in the rural and urban areas of Bangladesh. Strawberry is a highly perishable fruit, which cannot be stored for a longer period but different treatments along with natural edible coatings maintained the qualitative characteristics of stored fruits at ambient temperature condition. From the day, first onwards the loss in weight of fruits was noticed but calyx with peduncle along with garlic coating proved as the most effective one to control the weight loss, reduce disease incidence, disease severity and shelf life extension of strawberry fruits. Results revealed that the maximum TSS content (8.69%), disease incidence (55.54%) and severity (33.38%) were recorded in without calyx and peduncle plus control, while the minimum TSS content (6.87%), disease incidence (9.26%) and severity (5.40%) were observed in calyx with peduncle plus garlic extract, respectively. The longest shelf life (6.67 days) was obtained from calyx with peduncle plus garlic extracts, while the shortest shelf life was found from without calyx and peduncle plus control. Therefore, Therefore, it may concluded that combined treatment of calyx with peduncle plus garlic extract was found to be better in respect of reducing postharvest diseases, shelf life prolongation and quality retention of strawberry

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