Enhancing the postharvest quality attributes of banana (cv. Sabri) fruit by using chitosan, paraffin and coating oils

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Article Info	ABSTRACT
	The specific purpose of the present study was to explore the nutritional properties of bananas as exposed to various coating treatments. The single factor experiment was accompanied by a completely randomized design (CRD) with three replications. Among the physicochemical parameters; moisture content, total weight loss, and TSS increased with the duration of storage. On the other hand, dry matter, titratable acidity, and vitamin C content reduced during storage in the case of all the treated and untreated fruits. Paraffin coating caused minimal weight loss, whereas, the untreated fruits exhibited maximal weight loss. The peel color turned blackened within 8 days of storage in the untreated fruits, while sesame oil coating helped to keep it slightly green until day 10, but microbial decay was evident at the end of the storage time. Significant variation was found in extending the shelf life of banana. Among the treated and untreated fruits, paraffin coating and sesame oil coating showed the best performance. The fruits coated with paraffin and sesame oil coating showed the longest shelf life (10 days) which followed by olive oil coating (9.33 days). The shortest shelf life was detected in the untreated control fruits (8 days). This is an attempt to extend the shelf life of banana using readily available coating materials.

INTRODUCTION

Banana (*Musa* sp.) is the most common fruit crop in sub-tropical and tropical regions of the world. Banana is the largest herbaceous flowering plant (Picq et al. 2000). It belongs to the family *Musaceae*. The genus *Musa* originated in the Assam, Myanmar and Thailand (Khader et al. 1996). Banana founds the fourth most important global food product after rice, wheat and maize in terms of gross value of production (Arias et al. 2003). Banana is a popular, delicious, nutritious and affordable priced table fruit having a consumption rate higher than any other fruit in Bangladesh. It comprises of carbohydrate, crude fiber, protein, ash, phosphorus, fat, Calcium, Iron, ß-carotene, Riboflavin, Niacin and Ascorbic acid (Mondal and Rouf 2011). Amritasagar, Mehersagar, Sabri, Genasundori, Champa,

Singapuri etc., are some of the varieties grown in Bangladesh. In 2015-16, Bangladesh produces 798012 tonnes of bananas from 47412.56 ha of land (BBS 2016). The maintenance of the freshness of fruits and vegetables is one of the most important features of fruits and vegetables production in the tropics (Bachmann and Earles 2000). Losses in vegetables and fruits are of about 40 to 50% in the subtropics and tropics (Mejia 2003). At growing regions on ripening banana may prominently reduce the market value (Seifu 1999). Banana is a highly perishable fruit that is recognized to opposing physiological changes namely loss of weight due to transpiration and respiration, softening of flesh and lack of resistance capacity against microbial attack. Such spoilage causes extensive economic losses to both retailers and traders. In Bangladesh, a considerable amount of banana is decayed every year due to predominant humidity and high temperature. The enormity of postharvest damages of banana in Bangladesh ranges from 25-40% but it is merely 5-25% in developed countries (Kader 1992). Hassan (2010), stated that the postharvest loss of banana is 24.62% in Bangladesh which accounts for 566.7 crore taka annually. Therefore, prolongation of

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shelf life of banana is an utmost need to minimize the postharvest losses. Rao and Rao (1979) opined that for reducing the postharvest losses, banana fruits should be harvested at appropriate stage of maturity for the handling, transport and storage envisaged. It is indispensible to delay ripening for distant markets and then boost ripening for retail sale. Extension of shelf life may be done by several coating materials such as chitosan, wax coating, oil coating, plant extracts, etc. Edible coatings including cellulose, chitosan, starch, gum (polysaccharides), bees and polyvinyl acetate, paraffin wax (lipids), mineral oils and several proteins based (like gelatin and soy proteins) that proves noble barrier things without residue odor or taster impairment (Martin-Belloso & Fortuny, 2010; Dhall, 2013). Chitosan might be an ultimate preservative coating because of its biochemical properties, film forming properties, inherent antifungal properties and elicitation of phytoalexins (Jiang and Li 2001). Lower doses of chitosan may be used as a natural preservative of fruits alternative to unsafe formalin (Sakif et al. 2016). Mature green Cavendish banana coated with 1% chitosan and placed inside the Food Storage Chamber can delay ripening process (Pratiwi et al. 2015). Chitosan has been approved by the United State Food and Drug Administration (USFDA) as a Generally Retained as Safe (GRAS) food additive (Knorr 1986). Patil and Hulamani (1998) studied that the effect of posharvest treatments e.g. wax emulsion coating delayed ripening of babana. Dalal et al. (1970) reported that bananas at several stages of maturity treated with sisal-paraffin-sugarcane wax emulsions otherwise polyethylene emulsion before reduction of temp. Rao and Rao (1979) reported that color development and ripening were delayed when the fruits were treated with wax emulsion and stored in polythene bags. The shelf life and fruits quality were greater. Agnihotri and Ram (1971) observed that application of fungicidal wax emulsion was beneficial to minimize weight loss, spoilage and to delay ripening. No off-flavor was noticed in either oil-treated (by soybean, corn, peanut, linseed, and cottonseed oils) fruit by sensory evaluation (Zhiqiang et al. 2000). Wax and oil coatings have shown good performances in shelf life extension as well. Therefore, an attempt has been made to undertake research to observe the effects of various coating materials on shelf life and postharvest quality of banana.

MATERIALS AND METHODS

Experimental location

The experiment was accompanied in the research laboratory of the Department of Horticulture, and Department of Biochemistry & Molecular Biology of Bangladesh Agricultural University, Mymensingh. It was piloted during the month of July to October, 2017. The humidity and temperature of the storage room were recorded with a hygrometer and a thermometer, respectively. During the experimental period, temperature varies from 24.50-31.00 °C and Relative Humidity varies from 78-97%. The materials and methods used for the experiment are described below.

Experimental materials

The cultivar Sabri was used as experimental materials. Bananas were collected from a banana orchard of Sutiakhali village under Mymensingh Sadar Upazila. In the early morning two banana bunches were harvested and transferred to storage room (Postgraduate Laboratory), Department of Horticulture, BAU with careful handling to avoid injury. Then, the two bunches were pre-cooled by fan and both lower and upper 1-2 hands of the bunch were cut off for getting the experimental unit in uniform size. 120 fingers of banana having uniform shape, size and color were carefully chosen for the experiment.

A short description of the cultivar Sabri:

Sabri is one of the most popular marketable varieties of banana in Bangladesh. Bunches are pendant and peduncles pubescent. 7-10 hands are contained per bunch and each bunch contains 11-16 fingers. Finger is medium long with curvature. Peduncle is short and apex slightly nippled. Pericarp is average thick and pulp of the ripe fruit is soft with minor to divergent aroma. Sabri is a very popular variety of banana found in the tropics. It is an introduced banana variety in Bangladesh particularly in the Northern parts. It has sweet taste, aroma and also a high postharvest life. Sabri is an intermediate tall indigenous table banana variety that abides fruit in 18 months, yields almost 8-9 kg per bunch. This variety is susceptible to pest attack and disease infestation. Hence, post-harvest treatment in this variety is very much needed.

Methods

Mature green bananas of identical color, size and shape were nominated. The diseased, deformed, cracked or immature bananas were discarded. The bananas were washed in running water to remove dusts, soil or other foreign particles. Then they were dried in the open air and made ready for application of treatments.

Experimental treatments

The experimental treatments were as follows:

T0: Control

T1: 2.0% chitosan treatment

T2: Paraffin coating

T3: Almond oil coating

T4: Olive oil coating

T5: Sesame oil coating

T6: Coconut oil coating

T7: Mustard oil coating

Experimental design

The single factor experiment was completed in completely randomized design (CRD). There were 8 treatments each with three replications of five fruits per replication. Total 120 fruits were used for the experiment.

Application of experimental treatments

The selected fruits were indiscriminately assigned to the postharvest treatments. After the application of treatments, the fruits were preserved on a brown paper formerly placed on the table in the post-graduate laboratory room at ambient condition for observation. The procedures of applying the postharvest treatments were as follows.

(A) Control

15 fingers were selected randomly and settled with 3 replications and kept on the brown paper retained at ambient conditions (27±2°C and 84 to 87% RH) on the table in the laboratory.

(B) Chitosan treatment

Chitosan (2.0% concentrations) solution was prepared. Laboratory-prepared chitosan was obtained from Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh.

Preparation of chitosan

Fresh shrimps were collected at first step. Shrimp head and skin were parted from shrimp using sharp knife. The composed shrimp shell wastes were then washed with tap water and crinkled with mortar and pestle. Crinkled shrimp shell wastes were preserved in a polyethylene bags at ambient temperature (28±2°C) for 24 hours for partial autolysis to facilitate chemical extraction of chitosan and to improve the quality of chitosan (Toan 2009). There were largely 3 steps, namely demineralization, deproteinization and deacetylation were charted for the isolation of chitosan.

Preparation and application of chitosan solution

Using shrimp shell, chitosan of 2.0% concentrations were prepared using 0.6% acetic acid, accumulation 25% glycerol (w/w chitosan) as plasticizer. Each of the solutions was comprehensively mixed, filtered and the pH was adjusted to 5.6 using 1M sodium hydroxide.

Washed and air dried banana fingers were dipped into the solution for five minutes ensuring that enough quantity of the solution was being absorbed. Uncoated bananas (control samples) were occupied in a 0.6% glacial acetic acid solution at pH 5.6 for the same period of time. The treated and controlled banana samples were desiccated in ambient conditions (27±2°C and 84-87%) relative humidity). Then, the treated samples (control and coated bananas) were preserved at ambient conditions in the laboratory.

(C) Paraffin coating treatment

Randomly selected banana fingers were absorbed into paraffin for coating the fruits. Proper care has been taken during the immersion for the formation of identical thin transparent paraffin layer. The paraffin coated fruits were then instantaneously placed on the brown paper on the laboratory table at ambient condition for observation.

Oil coating treatment

For postharvest treatment of banana, five different oils (almond, olive, sesame, coconut and mustard oil) have been used. The banana fingers were coated with oils by hands wearing gloves to prevent any transmission of pathogen from hand to the fruits. Then the coated bananas were retained on the brown paper in the laboratory.

Studied parameters

1) Physical characters: Color, firmness, moisture content (%), dry matter (%).
2) Chemical characters: Tritratable acidity, vitamin C, total soluble solids (TSS)
3) Biological characters: Disease incidence (%), disease severity (%).
4) Shelf life.

Methods of studying the physico-chemical parameters

Among 5 fruits in each replication of each treatment, 2 fruits were used for destructive sampling at 4 days interval to inspect several parameters including moisture content, and TSS. The left over 3 fruits were used to investigate color, firmness, total weight loss, disease incidence, disease severity and shelf life. The physico-chemical parameters were estimated by using the methods cited in the Manual of Analysis of fruit and vegetable products (Ranganna 1979). The methods of studying aforementioned parameters are discussed below.

Color

Required days to reach changed stages of color during storage & ripening were determined accurately using numerical rating scale of 1-7, wherever 1 = green, 2 = breaker, 3 = < 25 %

yellow, 4 = < 50 % yellow, 5 = <75 % yellow, 6 = 75 to 100 % yellow, 7 = rotten/blackened.

Firmness

Days necessary to reach different stages of firmness for the period of storage and ripening were determined impartially using numerical rating scale of 1 to 5, wherever 1 = hard green, 2 = sprung, 3 = between sprung & eating ripe, 4 = eating ripe, 5 = over ripe. Same rating scale was used by Hassan (2006).

Determination of percent total weight loss

The banana hands used in this study were weighed using an electric balance then kept for storage. Percent total weight loss was calculated day-to-day by using the following formula:

$$\text{Total weight loss (\%)} = \frac{IW - FW}{IW} \times 100$$

Wherever, IW= Initial fruit weight & FW= Final fruit weight

Moisture content

Ten grams of banana pulp were weighed in a Petri dish from each treatment out of every replication. The Petri dish was sited in an electric oven at 80 °C for 72 hours till the weight became constant. It was then cooled and weighed again. As a final point, the percent moisture content of banana pulp was calculated by using the following formula.

$$\text{Percent moisture (\%)} = \frac{IW - FW}{IW} \times 100$$

Where, IW =Initial weight of fruit pulp, FW =Final weight of oven dried fruit pulp.

Dry matter content

Percent dry matter content of the fruit pulp was calculated from the data attained during moisture content estimation by using the following formula.

Percent dry matter = 100 − Percent moisture content.

Titratable acid content of banana pulp

Titratable acid content of banana pulp was calculated by using the method stated by Ranganna (1979). The following reagents were used for the determination of titratable acidity,

i. Standard NaOH solution (0.1N)

ii. 1% phenolphthalein solution

Extraction of banana juice from pulp

Ten grams of fruit pulp was taken and homogenized with distilled water (H_2O) in a blender. The blended materials were boiled for 1 hour under refluxing. The total mass was then transferred to a 100 mL volumetric flask and the volume was made up to the mark with distilled water.

Procedure

10 mL pulp solution was taken in a conical flask. 2-3 drops of phenolphthalein indicator was added and then flask was shaken energetically. It was then titrated instantaneously with 0.1 N NaOH solutions from a burette till a permanent pink color was appeared. The volume of NaOH solution required from titration was noted and per cent titrable acidity was calculated by using the succeeding formula:

$$\text{Percent titratable acidity} = \frac{T \times N \times V1 \times E}{V2 \times W \times 1000} \times 100$$

Where, T= Titre, N= Normality of NaOH, V1 = Volume made up,

E= Equivalent weight, V2 = Volume of extract, W = Weight of Sample

Vitamin C content

Reagents required for the estimation of vitamin C content of litchi pulp were (i) 3% Metaphosphoric acid (It was prepared by dissolving the sticks of HPO_3 in distilled water) (ii) Standard ascorbic acid solution and (iii) Dye solution (It was prepared by dissolving 260 mg of sodium salt of 2, 6-dichlorophenol indophenol in 1 liter of distilled water that enclosed 210 mg/liter of sodium bicarbonate). The subsequent steps were followed for the assessment of vitamin C.

Standardization of dye solution

In a conical flask 5 mL of standard ascorbic acid solution was taken and 5 mL of metaphasphoric acid (HPO_3) was added to it and was shaken. A micro burette was filled with dye solution. Then the mixed solution was titrated with dye using phenolphthalein indicator solution to a pink colored end point that continued at least for 15 seconds. By using the following formula, dye factor was calculated.

$$\text{Dye factor} = \frac{0.5}{\text{litre}}$$

Preparation of sample

In a 100 mL beaker, 10 grams of fresh fruit pulp was taken with 50 mL 3% metaphosphoric acid and then it was transferred to a blender and homogenized with identical concentration of metaphosphoric acid. After blending, it was filtered and centrifuged at 2000 rpm for 5 minutes. The homogenized liquid was transferred to a 100 mL volumetric flask and was made up to the mark with 3% metaphosphoric acid.

Titration

5 mL of the aliquot was taken in a conical flask and titrated with 2, 6-dichlorophenol dye. Phenolpthalein was used as indicator to pink colored end point that continued at least 15 seconds. The vitamin C content of the samples was calculated by using the following formula.

Vitamin C content (mg/100 g) =

$$\frac{T \times D \times V_1}{V_2 \times W} \times 100$$

Wherever, T = Titre, D = Dye factor, V_1 = Volume made up, V_2 = Volume of extract, W = Weight of sample

Total soluble solids (% Brix)

By using Abbe's refractometer, total soluble solids (TSS) content of banana fruit pulp was assessed. A drop of banana juice squeezed from the fruit pulp on the prism of the refractometer. Percent TSS was obtained from direct reading of the instrument. Temperature corrections were made by using the methods stated by Ranganna (1979).

Disease incidence

Disease incidence means percentage of bananas infected with diseases. The incidence of banana was noted at every 2 days intervals. The diseased fruits were acknowledged symptomatically. The disease incidence was estimated as follows.

Disease Incidence (%) = (Number of infected banana /Total number of banana) × 100

Disease severity

Disease severity represents the percentage diseased portion of infected banana. The infected fruits of each replication under every treatment were selected to determine percent fruit area infected. It was measured based on eye estimation.

Shelf life of banana

Shelf life of banana fruits as influenced by different postharvest treatments was estimated by counting the days prerequisite to ripe fully as to retaining optimum marketing and eating qualities.

Statistical analysis

The collected data on different parameters were analyzed statistically using MSTAT statistical package to find out the variation subsequent from experimental treatments following F variance test. The significance of difference in between the pair of means was compared by LSD test at 1% & 5% level of probability (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Changes in color

A significant variation was observed with regard to color changes of banana for the period of storage and ripening. The changes in color were the fastest in control (scores 1.0, 1.89, 5.89, 6.78, 7.00 and 7.00), whereas the changes were slower in those bananas coated with wax (scores 1.00, 1.00, 1.78, 3.22, 5.55 and 7.00) coating and sesame oil (scores 1.00, 1.11, 1.67, 2.89, 5.11, 5.83 and 6.33) coating (Table 1).

Changes in fruit firmness

Significant change in firmness was found in fruit firmness which might be as a result of the application of different treatments during storage. Higher rate of firmness scores (scores 1.00, 1.00, 2.44, 4.67, 4.83 and 5.00) were found in 2.0% chitosan treatment, whereas the rates were lower for paraffin (scores 1.00, 1.00, 1.11, 1.33, 2.56, 3.33 and 3.67) and sesame oil coating (scores 1.00, 1.00, 1.00, 1.11, 2.17, 3.67 and 4.00) treatments (Table 2).

Table 1. Effects of treatments on color change of banana (cv. Sabri) at different days after storage

Treatments	Color changes A in banana at different days after storage						
	0	2	4	6	8	10	12
T_0	1.00	1.89	5.89	6.78	7.00	7.00	7.00
T_1	1.00	1.33	5.56	6.67	6.75	7.00	7.00
T_2	1.00	1.00	1.78	3.22	5.55	7.00	7.00
T_3	1.00	1.00	2.56	6.22	6.83	7.00	7.00
T_4	1.00	1.11	4.78	6.22	6.78	7.00	7.00
T_5	1.00	1.11	1.67	2.89	5.11	5.83	6.33
T_6	1.00	1.11	2.44	6.00	6.67	7.00	7.00
T_7	1.00	1.44	2.22	5.78	7.00	7.00	7.00
$LSD_{0.05}$		0.03	0.11	0.15	0.19	0.16	7.00
$LSD_{0.01}$		0.04	0.15	0.20	0.27	0.23	7.00
Level of significance	-	**	**	**	**	**	**

* Significant at 5% level of probability; ** Significant at 1% level of probability.

Table 2. Effects of treatments on firmness of banana (cv. Sabri) at different days after storage

Treatments	Firmness scores A of banana at different days after storage						
	0	2	4	6	8	10	12
T_0	1.00	1.22	3.00	4.56	5.00	5.00	5.00
T_1	1.00	1.00	2.44	4.67	4.83	5.00	5.00
T_2	1.00	1.00	1.11	1.33	2.56	3.33	3.67
T_3	1.00	1.00	1.67	3.00	4.78	5.00	5.00
T_4	1.00	1.00	2.00	3.44	4.78	5.00	5.00
T_5	1.00	1.00	1.00	1.11	2.17	3.67	4.00
T_6	1.00	1.00	1.11	2.11	4.00	4.78	5.00
T_7	1.00	1.00	1.00	1.67	2.89	4.89	5.00
$LSD_{0.05}$		0.02	0.11	0.21	0.17	0.08	0.14
$LSD_{0.01}$		0.03	0.16	0.29	0.24	0.11	0.19
Level of significance	-	**	**	**	**	**	**

* Significant at 5% level of probability; ** Significant at 1% level of probability.

Total weight loss

Significant variation was observed with regard to total weight loss in fruits during storage. The higher rates of weight loss (4.08, 6.99, 10.86, 15.70 and 20.21%) were found in 2.0% chitosan. On the contrary, paraffin (0.30, 0.78, 1.77, 2.86 and 4.05) and olive oil (3.26, 5.98, 9.57, 12.84 and 17.08) had lower rates of weight losses (Table 3).

Moisture and dry matter content

Significant variation was observed in respect of moisture and dry matter content of banana during storage and ripening. The higher increasing rate of moisture content was found in fruits treated with paraffin coating (66.33, 72.67), whereas the lower rate was observed in olive oil (72.67, 74.00) treatment. In case of dry matter content, the higher decreasing rate was found in paraffin coating (33.67, 27.33), whereas the lower rate was recorded in olive oil (27.33, 26.00) treatment (Table 4).

Total soluble solids (TSS) content

The various postharvest coating treatments used in the present investigation exposed statistically significant variation in respect of total soluble solids (TSS) content at all days of storage. The highest TSS content (13.33, 26.00) was found

in chitosan treatment. By contrats, the lowest (5.33, 7.33) was found in paraffin coating (Table 5).

Titratable acidity and vitamin C content

Significant variation was observed in titratable acidity and vitamin C content of banana subjected to different postharvest treatments during storage. The maximum titratable acidity (0.42%) was recorded in banana kept in control condition at 4th day after storage, while the minimum titratable acidity (0.24%) was observed in bananas kept in paraffin coating at 8th day of storage. In case of vitamin C content, the highest vitamin C content (7.00 mg/100g) was recorded in bananas kept in control at 4^{rth} day of storage and the lowest vitamin C content (5.87 mg/100g) was found in bananas with chitosan coating at 8th days of storage (Table 6).

Disease incidence

Postharvest treatments exhibited significant variations in influencing disease incidence. Higher rates of disease incidence (0.00, 77.67, 88.67 and 100.00) were found in chitosan treatment, while the lower rates of disease incidence (0.0., 0.00, 33.00 and 88.67%) were found in sesame oil coating treatment (Table 7).

Table 3. Effects of treatments on percent weight loss of banana (cv. Sabri) at different days after storage

Treatments	Weight loss (%) of banana at different days after storage					
	0	2	4	6	8	10
T_0	317.33	4.39	7.31	11.80	15.91	21.25
T_1	309.67	4.08	6.99	10.86	15.70	20.21
T_2	339.67	0.30	0.78	1.77	2.86	4.05
T_3	318.00	3.67	6.08	9.12	12.78	16.35
T_4	306.67	3.26	5.98	9.57	12.84	17.08
T_5	323.67	4.52	7.31	10.21	12.57	15.45
T_6	336.33	3.48	5.85	8.52	11.40	15.17
T_7	312.00	4.17	5.98	8.76	11.44	14.96
$LSD_{0.05}$		1.04	0.29	0.26	0.35	0.23
$LSD_{0.01}$		1.43	0.39	0.36	0.49	0.31
Level of significance	-	**	**	**	**	**

* Significant at 5% level of probability; ** Significant at 1% level of probability.

Table 4. Effects of treatments on moisture and dry matter content (%) of banana (cv. Sabri) at different days after storage

Treatments	Moisture content (%)		Dry matter content (%)	
	Different days after storage			
	4	8	4	8
T_0	67.33	71.67	32.67	28.33
T_1	69.67	73.33	30.33	26.67
T_2	66.33	72.67	33.67	27.33
T_3	71.33	73.33	28.67	26.67
T_4	72.67	74.00	27.33	26.00
T_5	65.33	70.67	34.67	29.33
T_6	68.67	72.00	31.33	28.00
T_7	69.33	72.33	30.67	27.67
$LSD_{0.05}$	1.16	0.46	1.16	0.61
$LSD_{0.01}$	1.60	0.64	1.60	0.84
Level of significance	**	**	**	**

* Significant at 5% level of probability; ** Significant at 1% level of probability.

Disease severity

Postharvest treatments during storage significantly influenced the levels of disease severity. Disease severity levels were higher (21.11, 53.89, 75.00 and 95.56%) in chitosan treatment. However, the rates were lower (0.00, 3.33, 39.44 and 73.33%) in sesame oil treatment (Table 8).

Shelf life of banana

Significant variation was observed by applying the postharvest coating treatments in banana in relation to extension of shelf life. Among the treatments, paraffin coating and sesame oil coating were the best to prolong shelf life (10 days) as compared to control treatment (8 days) followed by almond oil (9 days) treatment.

DISCUSSION

The physico-chemical changes and shelf life of banana due to the application of different treatments were presented in this chapter. The data were noted at every alternate day after storage on selected physical, chemical and microbial properties and shelf life of banana. Edible coatings including cellulose, starch, chitosan, bees, gum (polysaccharides) and mineral oils, polyvinyl acetate, paraffin wax (lipids) and several proteins based (like soy proteins & gelatin) that evidences decent barrier properties without residue taste and odor impairment (Dhall 2013; Martin-Belloso and Fortuny 2010). Edible coating slow down senescence, respiration and enzyme activity; reduces moisture losses; conserves against mechanical damage and microbial growth; protect texture, color and flavor; thereabout, keeping up freshness, active volatile ingredients and plant antioxidants (Mahajan et al. 2014). Color is the sign as the criteria of quality of most of the fruits. Dull, grey skin color symptom development in banana is dependent on introduction temperature and time and susceptibility depends commonly on cultivar (Nakasone and Paull 1999). The changes in the color of the banana from green to yellow are the most obvious change which occurs during the storage of fruits. Changes in peel color during ripening and senescence of fruits involved either

Table 5. Effects of treatments on total soluble solids (TSS) of banana (cv. Sabri) at different days after storage

Treatments	Total soluble solids (ºBrix) of banana at different days after storage	
	4	8
T_0	16.33	26.67
T_1	13.33	26.00
T_2	5.33	7.33
T_3	9.00	18.33
T_4	14.00	16.00
T_5	6.67	7.00
T_6	7.67	19.33
T_7	5.33	12.00
$LSD_{0.05}$	0.33	0.38
$LSD_{0.01}$	0.45	0.52
Level of significance	**	**

* Significant at 5% level of probability; ** Significant at 1% level of probability.

chlorophyll degradation or qualitative and quantitative alterations of green pigment into other pigment (Beevers 1976). During color change pulp become softer and sweeter as the ratio of sugars to starch increases and the characteristics aroma is produced (Robinson 1996). The fruit character showed a gradual increase in color development under each of the different treatments. The increasing rate of color development is faster in bananas that are kept in control whereas bananas kept under treatment condition turned yellow slowly. All the treatments were successful in delaying the color change in comparison to the control. During storage condition, the firmness of banana pulp is usually changed from mature hard to eating ripe stage. All the treatments showed better performance than the control. Softening of fruits is related to the change of cell wall component and degradation of starch (Seymour 1993). Bananas kept in control became over ripe in day 8 whereas, all the treated fruits had prolonged firmness than that. Among the treatments, sesame oil and paraffin coatings showed better results. Paraffin coating had the best score (3.67) at day 12 while the other treatments achieved score 5 before. The result of the present study might be supported by the findings of Hernandez et al. (1999) and Siriboon

and Banlusilp (2004). Postharvest storage treatments used in the present investigation showed marked effects on total weight loss of banana during storage. Banana is subjects to shriveling and weight loss and its visual quality, if it is stored under conditions of low humidity (Esguerra and Rolle 2018). Coated pears showed a significantly reduced weight loss (Zhou et al. 2008). Sarker et al. (1997) observed that weight loss in banana fruit was linear with the storage temperature. The effect of storage treatment of fruits on total weight loss was highly significant in all stages of observation. The highest weight loss was 21.25% in fruits kept in control at day 12, while the lowest was 0.30% in fruits coated with paraffin at 2nd day of storage. Among the treatments, paraffin coating was the best in terms of controlling weight loss followed by sesame oil coating. At the 10th day of storage, the highest total weight loss (21.25%) was found in fruits under control condition while it was lowest (4.05%) in fruits with paraffin coating. This might be due to the formation of impermeable layer around the fruit surface by the coating materials. During the whole storage period the moisture content in the pulp of banana increased and the dry matter content decreased. Olive oil (T_4) showed the best performance in case of moisture and dry

Table 6. Effects of treatments on vitamin C and titratable acidity (TA) of banana (cv. Sabri) at different days after storage

Treatments	Vitamin C (mg/100g)		Titratable acidity (%)	
	Different days after storage			
	4	8	4	8
T_0	7.00	5.90	0.42	0.36
T_1	6.80	5.87	0.41	0.35
T_2	6.53	6.23	0.25	0.24
T_3	6.70	5.93	0.33	0.29
T_4	6.83	6.03	0.38	0.32
T_5	6.37	6.00	0.27	0.25
T_6	6.57	5.97	0.35	0.31
T_7	6.77	6.07	0.31	0.28
$LSD_{0.05}$	0.06	0.05	0.04	0.02
$LSD_{0.01}$	0.08	0.07	0.05	0.03
Level of significance	**	**	**	**

Table 7. Effects of coating treatments on disease incidence of banana (cv. Sabri) at different days after storage

Treatments	Disease incidence (%) of banana at different days after storage					
	2	4	6	8	10	12
T_0	0.00	11.00	66.00	100.00	100.00	
T_1	0.00	0.00	77.67	88.67	100.00	
T_2	0.00	0.00	33.00	66.33	66.67	100.00
T_3	0.00	11.00	33.00	88.67	100.00	
T_4	0.00	11.00	44.00	77.33	100.00	
T_5	0.00	0.00	0.00	33.00	88.67	
T_6	0.00	0.00	33.00	88.67	100.00	
T_7	0.00	0.00	22.00	100.00	100.00	
$LSD_{0.05}$			1.50	1.60	1.85	
$LSD_{0.01}$			2.07	2.21	2.55	
Level of significance	ND	ND	**	**	**	-

* Significant at 5% level of probability; ** Significant at 1% level of probability. ND Statistical analysis not performed.

matter contents. At day 4, the moisture content score for olive oil treated fruits was 72.67% and increased to 74.00% at day 8. In case of dry matter content, the percentage was 27.33%, which reduced to 26.00% at day 8. The result of the study goes in agreement with Elzayat (1996). At the 8th day of storage, percentage of TSS content was in the range between 26.67°Brix (Under control) and 7.00°Brix treated with (sesame oil). The maximum TSS content (26.67°Brix) was found in control fruits, while the minimum (7.00°Brix) was found in sesame oil treatment, followed by paraffin coating (7.33°Brix) treatment. The increase in the amount of total sugar related with ripening was due to the conversion of starch into sugars and breakdown of polysaccharides (Wills et al. 1989). The increase in TSS content is by reason of the conversion of complex carbohydrates into simple sugars. This is correlated with hydrolytic changes in starch and conversion of starch to sugar being a vital index of ripening process in mango and other climacteric fruits and supplementary hydrolysis decreased the TSS content during storage (Kittur et al. 2001). The effect of coating materials had a significant variation on titratable acid content of banana. In banana pulp, during ripening the total amount of acid increased (Seymour 1993). At 8th day of storage, the highest score (0.36%) was obtained by bananas kept in control condition whereas the lowest (0.24%) was gained by paraffin coating, again followed by sesame oil coated (0.25%) bananas. Titratable acidity was gradually decreased at all the treatments. The findings are similar with the experiment conducted by Reis et al. (2004) & Siriboon and Banlusilp (2004). The effect of coating materials was statistically significant in respect of vitamin C content (mg/100g) at different days after storage.

During ripening the reduction in vitamin C contents could be imposed to the oxidation of ascorbic acid by way of ripening progressed (Mondal et al. 1998). At day8, the highest score (6.23 mg/100g) was for paraffin coating treatment. The lowest (5.87 mg/100g) was achieved by chitosan coating

treatment. Vitamin C was gradually decreased at all the treatments. Parallel result was also obtained by Sarker et al. (1995) when the fruits were treated with Dithane M-45. Different postharvest diseases had been observed at storage period. The banana surface diseases were greatly influenced by postharvest treatments. Bananas with treatments in storage caused lower disease incidence as compared to those of control. No disease incidence was found at 2nd day of storage. At day 6, all the treatments were affected except the sesame oil treatment. At the 8th day of storage, the highest rate of disease incidence (100.00%) was found in control (banana left untreated) and the lowest rate of disease incidence (33.00%) was found in bananas that were coated with sesame oil. At day 10, paraffin coating was the best scorer. The less percentage of disease in the treated fruits may be possibly by the antimicrobial activity of the coating materials. Similar outputs were found by Ploetz and Galam (1998). The cause of lower disease percentages in treated bananas might be due to the formation of an impermeable layer which saved the fruits from the attack of pathogens, also might be for the antimicrobial properties of the coating materials. Bananas are prone to attack by decay-causing organisms which can promote the fast deterioration of quality of bananas. Bumpy handling of bananas can create wounds/injury that could serve as entry points for harmful microorganisms (Esguerra and Rolle 2018). Remarkable variation in disease severity was observed between the different treatments. The lowest disease level (0.00) was found in sesame oil coating and highest disease level (21.11%) was found in chitosan treatment at 6th day of storage. At the 8th day of storage all the treatments were affected where sesame oil showed the lowest score (3.33%). At 12th day after storage, the control was completely damaged (100%) whereas paraffin coating had the best score (60.00%) followed by sesame oil coating (73.33%) treated bananas. Mechanical damage and subsequent wastage were caused by microbial attack can be minimized by

Table 8. Effects of treatments on disease severity of banana (cv. Sabri) at different days after storage

Treatments	Disease severity (%) of banana at different days after storage					
	2	4	6	8	10	12
T_0	0.00	1.67	17.22	60.00	98.89	100.00
T_1	0.00	0.00	21.11	53.89	75.00	95.56
T_2	0.00	0.00	1.67	10.56	29.44	60.00
T_3	0.00	1.67	10.00	30.00	81.11	97.22
T_4	0.00	1.67	4.00	20.00	63.89	83.33
T_5	0.00	0.00	0.00	3.33	39.44	73.33
T_6	0.00	0.00	1.67	15.00	51.67	86.11
T_7	0.00	0.00	2.78	15.00	62.22	92.22
$LSD_{0.05}$			0.35	1.01	1.04	1.68
$LSD_{0.01}$			0.48	1.39	1.43	2.31
Level of significance	ND	ND	**	**	**	**

* Significant at 5% level of probability; ** Significant at 1% level of probability. ND Statistical analysis not performed.

Proper handling during harvesting (Wills et al. 1998). Most food processing functions, minimally processed fruits results in onward perishability and susceptibility to pathogenic and spoilage microorganisms (Alvarez et al. 2015). Shelf life of fruits (e.g. banana) is the epoch from harvesting up to the last edible stage. Keeping banana fruit in relatively low concentration of O_2 and high concentration of CO_2 can prolong storage life (Manzur et al. 2007). Results showed that the longer shelf life was observed in banana when they are coated with suitable coatings. Among the treatments, paraffin coating and sesame oil coating had longest shelf life (10 days) as compared to control treatment (8 days). Significant extensions of shelf lives were also obtained from olive oil (9.33 days), almond oil (9 days), and chitosan and coconut oil (8.67 days). Sensory, microbiological and nutritional shelf life of minimally processed fruit has usually of 7 days (Siddiqui et al. 2011). Reduced physiological process (e.g. respiration) and weight loss along with suppressed microbiological activity may possibly contribute to the extended shelf life of banana. These results are in agreement with the outcomes of Mondal et al. (2011).

CONCLUSIONS

Overall the results of the experiments showed that the postharvest treatments application caused significant effects on peel color, firmness, moisture and dry matter content, weight loss, TSS content, titratable acidity, vitamin C content, disease incidence and severity and shelf life of banana. Paraffin coating gave the better results on firmness, weight loss, disease incidence, disease severity and titratable acidity whereas sesame oil coating had the best score in color, moisture and dry matter content. More or less similar performance was also found with other oil coating treated fruits of banana. Chitosan coating had the lowest performance among all the treatments. The maximum physico-chemical changes occurred in

control, whereas the changes were the minimum in fruits under treatment.

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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