Trends in
Horticultural Research

Research Article
Effects of Different Coating Materials on Shelf Life and Quality of Mango

[1]Md. Zafrul Hasan, [2]Md. Amirul Islam, [3]Md. Hasibur Rahaman Hera, [4]Md. Niaz Morshed and [5]Md. Kamrul Hassan

[1]Bangladesh Agricultural Development Corporation, Dhaka, Bangladesh
[2]Sustainable Intensification Program, International Maize and Wheat Improvement Center, Bangladesh
[3]Plant Pathology Division, Bangladesh Rice Research Institute, 1701 Gazipur, Bangladesh
[4]Adaptive Research Division, Bangladesh Rice Research Institute, 1701 Gazipur, Bangladesh
[5]Department of Horticulture, Bangladesh Agricultural University, 2202 Mymensingh, Bangladesh

Abstract

Background and Objective: Mango fruits being climacteric have a short shelf life and coating is considered as one of the most popular techniques to prolong its shelf life. This study was carried out to compare chitosan with different other coating materials in order to extend shelf life and to maintain quality of mango. **Materials and Methods:** The experiment was laid out in RCBD and comprised eight treatments viz., control, fruit coating with 2% chitosan, paraffin wax, almond oil, olive oil, sesame oil, coconut oil and mustard oil. **Results:** Some of the attributes such as; total weight loss, total soluble solids, moisture content, disease incidence and disease severity increased, while dry matter content, titratable acidity and vitamin C content decreased with the increase in duration of storage. In case of weight loss, the highest rate was observed in control, while lowest was in paraffin coating. The highest total soluble solids (14.67%) was noticed in fruits coated with 2% chitosan and the lowest (12.67%) was in olive oil coating and mustard oil coating at the 8th day of storage. Highest moisture content was recorded in almond, sesame and coconut oil coated fruits and lowest moisture content (83.67%) was observed in fruits coated with 2% chitosan. No treatment fruits were more susceptible to postharvest diseases. Shelf life varied with paraffin coating had the longest shelf life (12 days). **Conclusion:** Almond oil and paraffin coating gave the best result in reduction of disease, reduction of weight loss and firmness respectively, which resulted, prolonged shelf life of mango.

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Mango (*Mangifera indica* L.) an excellent fruit belongs to the genus *Mangifera*, consisting of numerous species of tropical fruit plants belongs to the family Anacardiaceae. It is the most important tropical fruit crop after banana and plantains[1]. The mango is native to South Asia, from where it has been distributed worldwide to become one of the most cultivated fruits in the tropics. It is considered as the national fruit of India, Pakistan and Philippines, while it is the national tree of Bangladesh. It is now recognized as one of the best fruits of all indigenous fruits due to its excellent flavor, attractive fragrance and beautiful shades of color, delicious taste and high nutritive value. In Bangladesh, near about 250 varieties of mangoes are grown[2].

The mango is indigenous to the Indian subcontinent for 4000 years. Asia is the main producer with 76.9% of the total world production, followed by USA with 13.38%, Africa with 9% and less than 1% each for Europe and Oceania[3]. In Bangladesh at present, mango occupied 25.22% garden area under fruits[4]. In 2017-18, it occupied 109584 acres of land and total production is 1165804 metric tons whereas, in 2015 the area and production of mango were 93480 acres and 1161685 metric tons, respectively[4].

Due to favorable climates, huge quantities of mangoes are produced each year in Bangladesh. However, a considerable proportion of mango fruit is spoiled each year due to lack of proper storage and marketing infrastructures. Hence, adequate measures should be taken to prolong shelf life of mangoes. Storage is essential for extending the consumption period of fruits, regulating their supply to the market and also for transportation to long distances. Shelf life of fruits could be extended by precooling, chemical treatments, low temperature, different botanical extracts and so on. However, different botanical extracts viz., neem, aloe vera and garlic influence the shelf life and maintain quality of mangoes. The combination of Modified Atmospheric Packaging (MAP) with effective decay control measures can extend the postharvest life of mango fruit[5]. Storage life of fruits is affected by storage temperature because higher temperature increases respiration rate, leading to fruit softening and at low temperature, storage metabolism is retarded by a reduction in respiration rate, color change and softening[6]. Due to mishandling, inadequate storage or lack of postharvest technical knowledge, producers and traders have to face about 27% losses[7].

Mango being one of the most important fruits, efforts towards reduction of postharvest losses should be of top priority. The postharvest life of any fruit consists of ripening and senescence. The ripening and subsequent senescence are the sum total of a number of postharvest changes. Thus prolonging storage life of a fruit consists in slowing down the processes leading to ripening and if possible in stopping the changes that cause senescence after ripening. Hence, it is necessary to understand the postharvest physiology of mango in order to develop and apply adequate postharvest technologies such as; hot water treatment, stored in polythene bag, use of fungicide and $KMnO_4$ in polythene bags, stored in low temperature i.e., refrigeration at different low temperature, paper wrapping, plastic films for atmospheric modification etc., to fulfill the requirements of national and international trade through prevention of postharvest losses. Postharvest losses and physiological changes in mangoes have been studied by Subramanyam *et al.*[8]. Considerable study in the physiochemical processes has been done on mango in many countries of the world, but little information on ashwina (a mango variety) is available in the scientific literature[9]. Ashwina is commercially very important because of its coming to the market last of all varieties and in large quantities. Even though its quality is not so good, it has a high price because of its late arrival and continuance in the market place for a long period of time. So, it is necessary to understand the shelf life of mango considering different factors to avoid postharvest losses.

Coating might be an important substance to prolong shelf life of mango by minimizing physiological processes and microbial decay. Though chitosan is useful for shelf life but readily available paraffin and different types of oils like almond oil, olive oil, sesame oil, coconut oil and mustard oil etc., may be investigated to find out their effects on shelf and quality of mango. Effects of coating materials, especially with regards to mango on postharvest quality are very scanty in the scientific literature in Bangladesh. At the same time, very little systematic study has so far been conducted in Bangladesh to reduce the postharvest losses and extension of shelf life of mango. Therefore, this present study was aimed (a) to compare chitosan with other coating materials in prolonging shelf life and quality of mango and (b) to investigate the physico-chemical and microbial attributes of mango as affected by coating materials.

MATERIALS AND METHODS

Experimental location: The experiment was carried out at the laboratories of the Department of Horticulture and the Department of Biochemistry and Molecular Biology, Bangladesh Agricultural University, Mymensingh during the period from July-October, 2017. The temperature and relative humidity of the storage room were recorded during this period.

Experiment details: The single-factor experiment was laid out in the completely randomized design with three replications of 5 fruits. A total of 120 fruits of more or less similar shape and size and free of visible disease symptoms were harvested. The skin adherences, dots and latex were cleaned by gently wiping the fruits with moist and clean towel. There were 8 treatments combinations. Each treatment combination comprised 15 fruits.

The experimental materials were mature hard fruits of variety Ashwina. Mangoes used in this experiment were collected from Chapai Nawabganj on 20 July, 2017. The experimental treatments for this study are:

T_0 : Control
T_1 : Fruits coated with 2% chitosan
T_2 : Fruits coated with paraffin
T_3 : Fruits coated with almond oil
T_4 : Fruits coated with olive oil
T_5 : Fruits coated with sesame oil
T_6 : Fruits coated with coconut oil and
T_7 : Fruits coated mustard oil

Fifteen fruits were randomly selected from the experimental fruit lot for each of the coating materials. The selected fruits were then individually coated with oils and placed on the laboratory table at ambient condition for observation.

Methods of application of postharvest treatments: The postharvest treatments were randomly assigned to the experimental fruits. The treated fruits were kept on brown papers that were previously placed on laboratory table at ambient condition. About 120 fruits were randomly divided to place 15 fruits in each treatment for this experiment. Then the fruits were subjected to the following treatments as per the experimental design:

- **Control:** Fruits of each variety were randomly selected from the lot and the fruits were kept on brown paper placed on the laboratory table at ambient conditions
- **Chitosan treatment:** Chitosan was isolated by using the method of Hossain and Iqbal[10]. Chitosan 2.0% solutions were prepared using 0.6% acetic acid, adding 25% glycerol (w/w chitosan) as plasticizer. Solution was thoroughly mixed, filtered and the pH was adjusted to 5.6 using 1 M sodium hydroxide Mango fingers which were

washed and dry were dipped into the solution for 5 min until enough amount of solution was being absorbed. Uncoated mangoes (control samples) were immersed in a 0.6% glacial acetic acid solution at pH 5.6 for the same duration of time. The treated and control samples were dried in conditions i.e., $26\pm2°C$ and 40-50% relative humidity. Then, the treated samples control and coated mangoes were placed in the laboratory at ambient conditions

- **Paraffin coating:** Randomly selected mango fingers were immersed into paraffin for coating the fruits. Care has been taken during the immersion for the formation of very thin transparent paraffin layer. The paraffin coated fruits were then immediately placed on the brown paper on the laboratory table at ambient condition for observation
- **Oil coating:** Five different oils (almond, olive, sesame, coconut and mustard) have been used for postharvest treatment of mango. The mango fingers were coated with oils by hands wearing gloves to prevent any transfer of pathogen from hand to the fruits. Then the coated mangoes were placed on the brown paper in the laboratory

Data collection: In this experiment the following parameters were studied:

- Physical parameters i.e., colour, firmness, weight loss, moisture content, dry matter content
- Chemical parameters i.e., total soluble solids, titratable acidity, vitamin C content
- Microbial characters i.e., disease incidence (%) and disease severity (%) and shelf life. During the entire period of storage, the experimental fruits was observed every day and data were recorded each alternate day

Methods of studying parameters listed above
Physical parameters

- **Colour and firmness:** Days required to reach different stages of colour and firmness during storage and ripening. Both were determined objectively using numerical rating scale of 1-7 and 1-5, respectively:
- **Estimation of total weight loss, moisture content and dry matter content:** Total weight loss (%) was calculated at 2 days intervals. Ten gram of fruit pulp was weighed in a porcelain crucible (which was previously cleaned, dried and weighed) from each treatment and replications. The crucible was placed in electric oven at 80°C for 72 h until

the weight became constant. It was then cooled in desiccators and weighed again. Moisture content (%) was calculated by using the formula[11]:

$$\text{Moisture content } (\%) = \frac{\text{IW} - \text{FW}}{\text{IW}} \times 100$$

Where:
IW = Initial weight of fruit pulp (g)
FW = Final weight of oven dried fruit pulp (g)

Percentage of dry matter content of the pulp was calculated from the data obtained during moisture estimation using the following formula:

$$\text{Dry matter } (\%) = 100 - \text{Moisture content } (\%)$$

Chemical parameters

- **Estimation of total soluble solids content:** Total soluble solids content of mango pulp was estimated by using Abbe's Refractometer. A drop of mango juice squeezed from the fruit pulp on the prism of the refractometer. Percentage of TSS was obtained from direct reading of the instrument. Temperature corrections were made by using the methods described by Ranganna[12]:
- **Titratable acidity (TA):** Titratable acidity was estimated chemical analysis process by using mango pulp stored in refrigerator. Titratable acidity was declined slowly when stored in low temperature. The titratable acidity of mango pulp was determined by method of Ranganna[12]. The following reagents were used for the determination of titratable acidity:

- Standard NaOH solution (0.1 N)
- 1% phenolphthalein solution

Extraction of mango juice: Ten gram of fresh mango pulp was taken in a 500 mL beaker and then it was homogenized with distilled water in blender. The blender materials were then filtered and transferred to 500 mL volumetric flask and the volume was made up to the mark with distilled water:

- **Procedure:** Five milliliters of pulp solution was taken in a conical flask. Two to three drops of phenolphthalein indicator solution was added and then the conical flask was shaken vigorously. It was then titrated immediately with 0.01 N NaOH solution from a burette till a permanent pink colour was appeared. The volume of NaOH solution required for the titration

was noted from burette reading. Percentage of titratable acidity was calculated by using the following formula[12]:

$$\text{Titratable acidity } (\%) = \frac{\text{T} \times \text{N} \times \text{V}_1 \times \text{E}}{\text{V}_2 \times \text{W} \times 1000} \times 100$$

Where:
T = Titre
N = Normality of NaOH
V_1 = Volume made up
E = Equivalent weight of acid
V_2 = Volume of sample taken for estimation and
W = Weight of sample taken

- **Vitamin C content:** Ascorbic acid content was determined according to the method of Ranganna[12]. The following reagents were used for the estimation of vitamin C content:

- Three percent metaphosphoric acid (HPO_3). It was prepared by dissolving the sticks of HPO_3 in distilled water
- Standard ascorbic solution 10 mg% of L-ascorbic acid solution was prepared by dissolving ascorbic acid in 3% metaphosphoric acid solution
- Dye solution

It was prepared by dissolving 50 mg of the sodium salt of 2,6-dichlorophenol indophenol in approximately 50 mL of hot distilled water containing 42 mg of sodium bicarbonate. It was then cooled and diluted to 100 mL with distilled water. The following steps were followed for the estimation of ascorbic acid.

Standardization of dye solution: Ten milliliters of standard ascorbic acid solution was taken in a conical flask and 5 mL of metaphosphoric acid HPO_3 was added to it. A micro burette was filed with the dye solution. The content of the conical flask was titrated with dye solution. The content of conical flask was titrated with dye till the pink-coloured end point appeared. The milliliters of dye solution required to complete the titration was recorded. Dye factor was calculated using the following formula of Ranganna[12]:

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

Preparation of sample: About 5 g of fresh fruit and 35 mL of 3% metaphosphoric acid solution was taken in a blender and

homogenized for 2 min. After blending it was filtered and centrifuged at about 2000 ppm for 5 min. The supernatant homogenized liquid was transferred to a 50 mL volumetric flask and the volume was made up with 3% metaphosphoric acid.

Procedure: Ten milliliters of the aliquot was taken in a conical flask and titrated with dye solution. The ascorbic acid content of the samples was calculated by using the following formula of Ranganna[12]:

$$\text{Ascorbic acid content (mg/100 g)} = \frac{T \times D \times V_1}{V_2 \times W} \times 100$$

Where:
T = Titre
D = Dye factor
V_1 = Volume made up (mL)
V_2 = Volume of extract used for titration and
W = Weight of sample (g)

Microbial characters

• **Assessment of disease incidence:** The fruits were critically examined 1 day later for the appearance of rot. The incidence of fruit rot was recorded after 1 day. The first count was made at the 3 days after storage. Diseases incidence means percentage of fruits infected with disease. This is measured by calculating the percentage of fruits infected in each replication of each treatment. The diseased fruits were identified symptomatically. The disease incidence was calculated as follow[13]:

$$\frac{\text{Disease}}{\text{incidence (\%)}} = \frac{\text{Number of infected fruits in each replication}}{\text{Total number of fruits in each replication}} \times 100$$

• **Disease severity:** The percentage was recorded 5 times starting at the 3 days after storage. Infected fruits were selected to determine percent fruit area infected. The percentage of fruit area diseased was measured based on eye estimation. Later, the means were calculated

• **Estimation of shelf life:** Shelf life of mango was calculated by counting the days required to ripe fully as to retaining, optimum marketing and eating qualities

Statistical analysis: The collected data were statistically analyzed by Analysis of Variance (ANOVA) tests. The mean of different parameters was compared by DMRT (Duncans' Multiple Range Test) as Gomez and Gomez[14]. The collected data on various parameters were statistically analyzed using MSTAT statistical package. The means for all the treatments were calculated and Analysis of Variances (ANOVA) for all the parameters was performed by F-test. The significance of difference between the pairs of means was compared by Least Significant Difference (LSD) test at the 1 and 5% levels of probability[14].

RESULTS

The data were recorded at every alternate day after storage for experiment on selected physical, chemical and microbial properties and shelf life of mango. Results are presented for this experiment below.

Color: Significant variation was observed in respect of color changes of mango during storage and ripening. The changes in color were faster (scores; 1.00, 1.67, 2.00, 3.67, 7.00, 7.00 and 7.00) in mangoes coated in control, whereas the changes were slower (scores; 1.00, 1.56, 1.89, 1.89, 4.78, 5.33 and 5.89) in those mangoes coated with almond oil (Table 1).

Firmness: Statistically highly significant variation was observed in respect of firmness of mango during storage. Faster rates of firmness (scores; 1.00, 2.22, 3.11, 4.11, 5.00, 5.00 and 5.00) were found in mangoes coated with 2% chitosan. On the contrary, the rates of firmness changes were slower in mango fruits coated with paraffin (scores; 1.00, 1.22, 1.67, 1.89, 2.44, 4.22 and 5.00) and sesame (scores; 1.00, 1.33, 1.44, 2.33, 3.33, 4.11 and 5.00) oil as presented in Table 2.

Weight loss of mango: Weight loss of mango fruits trended to increase with the advancement of storage period. Weight losses were found to be higher in control mangoes as compared to those coated with different coating materials. The highest weight loss (19.32%) was observed in control mangoes at the 14th day of storage, whereas the lowest weight loss (3.27%) was observed in fruits coated with paraffin at the same day of storage as presented in Table 3. Among the coating materials, paraffin resulted in the best in terms of controlling weight loss of mango during storage.

Moisture content of pulp, dry matter content, Total Soluble Solids (TSS), titratable acidity and vitamin C content: All parameters showed significant variation at the 4th and 8th days of storage. While moisture content and Total Soluble Solids (TSS) increased with the increase in storage duration,

Table 1: Effect of different coating materials treatments on color of mango (cv. ashwina) at different days after storage

Treatments	Colour scores[A] of mango at different days after storage						
	1	2	4	6	8	10	12
T_0 = Control	1.00	1.67	2.00	3.67	7.00	7.00	7.00
T_1 = Chitosan 2%	1.00	1.44	1.89	2.56	5.56	6.00	6.44
T_2 = Paraffin coating	1.00	1.67	2.00	2.56	3.78	4.78	7.00
T_3 = Almond oil coating	1.00	1.56	1.89	1.89	4.78	5.33	5.89
T_4 = Olive oil coating	1.00	1.33	2.00	3.11	6.44	7.00	7.00
T_5 = Sesame oil coating	1.00	1.44	1.78	2.00	6.44	7.00	7.00
T_6 = Coconut oil coating	1.00	1.33	1.67	2.78	6.44	7.00	7.00
T_7 = Mustard oil coating	1.00	1.44	1.56	2.78	5.22	5.89	5.89
$LSD_{0.05}$		0.07	0.04	0.17	0.27	0.21	0.13
$LSD_{0.01}$		0.09	0.06	0.23	0.38	0.29	0.18
Level of significance	-	**	**	**	**	**	**

[A]colour scores, 1: Green, 2: Breaker, 4: <25% yellow, 6: 25-<50% yellow, 8: 50-< 75% yellow, 10: 75-< 100% yellow, 12: Blackened/rotten, **Significant at 1% level of probability

Table 2: Effect of different coating materials treatments on firmness of mango (cv. ashwina) at different days after storage

Treatments	Firmness scores[A] of mango at different days after storage						
	1	2	4	6	8	10	12
T_0 = Control	1.00	1.89	3.00	4.00	5.00	5.00	5.00
T_1 = Chitosan 2%	1.00	2.22	3.11	4.11	5.00	5.00	5.00
T_2 = Paraffin coating	1.00	1.22	1.67	1.89	2.44	4.22	5.00
T_3 = Almond oil coating	1.00	1.56	2.00	2.22	3.00	4.56	5.00
T_4 = Olive oil coating	1.00	1.67	1.89	2.67	3.56	4.33	5.00
T_5 = Sesame oil coating	1.00	1.33	1.44	2.33	3.33	4.11	5.00
T_6 = Coconut oil coating	1.00	1.89	2.56	3.44	4.00	4.67	4.89
T_7 = Mustard oil coating	1.00	1.67	1.78	2.78	3.11	3.89	4.78
$LSD_{0.05}$		0.15	0.25	0.23	0.27	0.27	0.02
$LSD_{0.01}$		0.20	0.35	0.31	0.37	0.37	0.03
Level of significance	-	**	**	**	**	*	**

[A] Firmness scores: Over ripe (1, 2, 4, 6, 8, 10 and 12 days),*Significant at 5% level of probability, **Significant at 1% level of probability.

Table 3: Effect of different coating materials treatments on weight loss (%) of mango (cv. ashwina) at different days after storage

Treatments	Weight loss (%) at different days after storage						
	0	4	6	8	10	12	14
T_0 = Control	1231.33	4.29	7.20	9.36	11.92	15.67	19.32
T_1 = Chitosan 2%	998.00	3.94	6.95	9.19	11.88	14.53	17.14
T_2 = Paraffin coating	1205.00	0.50	0.91	1.24	1.66	2.07	3.27
T_3 = Almond oil coating	1268.00	2.96	4.36	5.53	7.22	9.17	10.85
T_4 = Olive oil coating	1323.33	2.50	4.65	6.47	8.21	10.58	12.49
T_5 = Sesame oil coating	1313.00	2.55	4.70	7.03	8.25	10.58	12.50
T_6 = Coconut oil coating	1283.00	2.78	4.99	7.39	8.65	10.88	13.25
T_7 = Mustard oil coating	1790.00	2.30	4.39	6.09	7.63	9.75	11.72
$LSD_{0.05}$		0.79	0.29	0.41	0.27	0.50	1.14
$LSD_{0.01}$		1.09	0.40	0.57	0.37	0.69	1.58
Level of significance	-	**	**	**	**	**	**

(Here 0, 4, 6, 8, 10, 12 and 14 days), **Significant at 1% level of probability

dry matter content, titratable acidity and Vitamin C content showed reverse character. Higher levels of moisture were found in mangoes coated with different oils (almond oil coating, sesame oil coating and coconut oil coating and olive oil coating) as compared to the untreated control and chitosan. On the other hand, higher levels of dry matter were found in mangoes coated with 2% chitosan as compared to the different oils (almond oil coating, sesame oil coating and coconut oil coating and olive oil coating). At the 4th day of storage, TSS content was (13.67%) in control and this is the maximum TSS content while the minimum TSS content (11.33%) was found in paraffin coating treatment at the 4th day of storage. At the 8th day of storage, TSS content of fruits was 14.67% in case of 2% chitosan treatment and this was the maximum while the minimum TSS content was found in the mustard oil and olive oil coated fruits (12.67%) at the 8th day of storage.

Table 4: Effect of treatments on percent moisture content, dry matter content, Total Soluble Solids (TSS) content, titratable acidity and vitamin C content of mango (cv. ashwina) at different days after storage

	Parameters									
	Different days after storage									
	Moisture content		Dry matter content		Total soluble solids content		Titratable acidity		Vitamin C content	
Treatments days	4	8	4	8	4	8	4	8	4	8
T_0 = Control	78.33	86.67	21.67	13.33	13.67	14.33	1.10	0.75	18.79	16.30
T_1 = Chitosan 2%	77.67	83.67	22.33	16.33	13.33	14.67	1.46	0.89	25.20	22.79
T_2 = Paraffin coating	83.00	84.00	17.00	16.00	11.33	14.00	1.73	1.13	24.82	22.28
T_3 = Almond oil coating	82.00	87.33	18.00	12.67	12.00	13.00	1.23	0.87	28.19	25.52
T_4 = Olive oil coating	86.00	87.00	14.00	13.00	11.67	12.67	2.00	1.40	24.70	22.20
T_5 = Sesame oil coating	82.00	87.33	18.00	12.67	12.67	14.33	1.13	0.76	22.49	19.91
T_6 = Coconut oil coating	80.33	87.33	19.67	12.67	12.33	13.33	1.73	1.29	29.88	27.45
T_7 = Mustard oil coating	82.00	87.00	18.00	13.00	11.67	12.67	2.50	1.75	32.47	29.97
$LSD_{0.05}$	0.73	0.72	0.80	0.38	0.25	0.17	0.07	0.06	0.72	0.70
$LSD_{0.01}$	1.01	0.99	1.10	0.52	0.34	0.23	0.09	0.08	0.99	0.96
Level of significance	**	**	**	**	**	**	**	**	**	**

** Significant at 1% level of probability

Table 5: Effect of treatments on disease incidence (%) of mango (cv. ashwina) at different days after storage

	Disease incidence (%) at different days after storage					
Treatments	2	4	6	8	10	12
T_0 = Control	0.00	0.00	33.00	100.00	100.00	100.00
T_1 = Chitosan 2%	0.00	0.00	11.00	66.33	77.33	88.67
T_2 = Paraffin coating	0.00	0.00	11.00	33.00	55.00	100.00
T_3 = Almond oil coating	0.00	0.00	0.00	55.33	66.33	77.67
T_4 = Olive oil coating	0.00	0.00	22.00	88.67	100.00	100.00
T_5 = Sesame oil coating	0.00	0.00	0.00	88.67	100.00	100.00
T_6 = Coconut oil coating	0.00	0.00	22.00	88.67	100.00	100.00
T_7 = Mustard oil coating	0.00	0.00	22.00	66.33	77.67	77.67
$LSD_{0.05}$			5.36	6.94	6.41	2.72
$LSD_{0.01}$			7.39	9.56	8.83	3.74
Level of significance	ND	ND	**	**	**	**

*Significant at 5% level of probability, **Significant at 1% level of probability, ND: Statistical analysis not done

The maximum titratable acidity (2.50 and 1.75%) were recorded in mango fruits coated with mustard oil at the 4th and 8th days of storage, respectively. On the other hand, the minimum titratable acidity (1.10 and 0.75%) were observed in the untreated control fruits at the same days of storage. The maximum vitamin C content (32.47 and 29.97%) were recorded in mustard oil coated fruits at the 4th and 8th days of storage, respectively, while the minimum vitamin C content (18.79 and 16.30%) were observed in the untreated control mangoes at the same days of storage as shown in Table 4.

Disease incidence: There was highly significant variation in the incidence of disease on different dates of counting. No fruits were found to be diseased till the 4th day of storage. Disease incidence was observed on the 6th day of storage. Overall, the oil coated fruits amply suppressed the disease growth during the period of investigation. The treatments,

namely T_3 and T_7 performed the best in reducing postharvest spoilage of mangoes as compared to other treatments as Table 5 represents.

Disease severity: There were no visible diseases until day 4 of storage. After that disease started to become visible and there were significant variation among the treatments. Results revealed that sesame oil coating performed the best in keeping the disease level down throughout the storage period followed by almond oil coating. At the 14th day of storage, the lowest disease severity (29.44%) was observed in fruits coated with sesame oil, whereas the level was the highest in the case of untreated control and olive oil coated fruits as presented in Table 6.

Shelf life: In the present investigation, highly significant variation was observed on shelf life of mango as influenced by

Table 6: Effect of different coating treatments on disease severity (%) of mango (cv. ashwina) at different days after storage

Treatments days	Disease severity (%) at different days after storage						
	2	4	6	8	10	12	14
T_0 = Control	0.00	0.00	1.67	12.22	32.22	60.00	69.44
T_1 = Chitosan 2%	0.00	0.00	1.67	11.11	18.89	34.44	39.44
T_2 = Paraffin coating	0.00	0.00	0.56	3.89	9.44	30.00	36.67
T_3 = Almond oil coating	0.00	0.00	0.00	2.78	12.22	23.33	32.22
T_4 = Olive oil coating	0.00	0.00	1.11	12.78	37.22	50.00	56.67
T_5 = Sesame oil coating	0.00	0.00	0.00	7.22	11.11	23.00	29.44
T_6 = Coconut oil coating	0.00	0.00	1.67	14.44	27.22	41.67	49.44
T_7 = Mustard oil coating	0.00	0.00	1.67	6.67	16.11	25.56	37.22
$LSD_{0.05}$			0.18	0.96	1.57	2.20	7.34
$LSD_{0.01}$			0.25	1.32	2.16	3.03	10.12
Level of significance	ND	ND	**	**	**	**	**

*Significant at 5% level of probability, **Significant at 1% level of probability, ND: Statistical analysis not performed
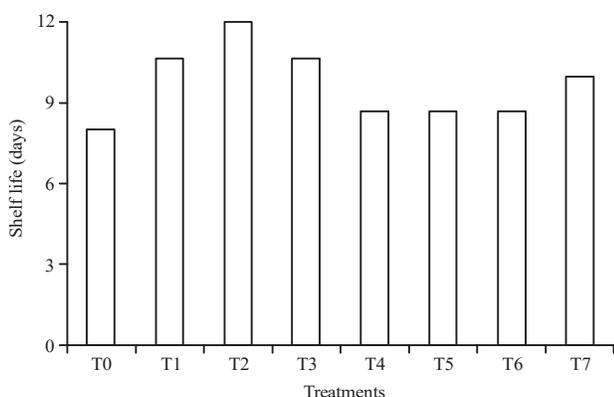
Fig. 1: Effects of different post harvest treatments on shelf life of mango

T0: Control, T1: Chitosan 2%, T2: Paraffin coating, T3: Almond oil coating, T4: Olive oil coating, T5: Sesame oil coating, T6: Coconut oil coating, T7: Mustard oil coating

chitosan and oil coatings. The longest shelf life of 12 days was observed in the paraffin coated fruits followed by chitosan and almond oil coatings (10.67 days). Mustard oil also significantly extended shelf life of mango (Fig. 1).

DISCUSSION

Color is considered as one of the most important criteria of quality of most fruits. The changes in color were faster in control, whereas the changes were slower in those mangoes coated with almond oil. The result of the present study is supported by the findings of Robinson *et al.*[15] and Gowda and Huddar[16]. They found that during colour changes the pulp of the fruit became softer and sweeter as the ratio of sugars to starch increased and the characteristics aroma was produced. Firmness is also considered as one of the most

important criteria of fruits quality. Faster rates of firmness were found in mangoes coated with 2% chitosan. On the contrary, the rates of firmness changes were slower in mango fruits coated with paraffin. Weight loss of mango increased with the advancement of storage period. The highest weight loss was observed in control mangoes at the 14th day of storage, whereas the lowest weight loss was observed in fruits coated with paraffin at the same day of storage. Among the coating materials, paraffin resulted in the best in terms of controlling weight loss of mango during storage. These results are further in line with Gowda and Huddar[16], who observed that mature green alphanso and other 7 varieties of mango fruits were influenced by size of fruit, storage temperature, variety and the reduction in length and thickness of fruits during ripening process were attributed to shrivelling of fruits due to higher percent loss of water (12.8%) from fruits when stored at high temperature (18-34°C). The variation among the treatment was significant in respect of moisture content at the 4th and 8th days of storage. Higher levels of moisture were found in mangoes coated with different oils (almond oil coating, sesame oil coating and coconut oil coating and olive oil coating) as compared to the untreated control and chitosan. The increased moisture content was probably due to osmotic withdrawal of water from peel to pulp and complete breakdown of starch to CO_2 and water. Total increase in this process was probably more than loss of water due to transpiration and hydrolysis.

The various postharvest coating treatments used in the present investigation showed statistically significant variation in respect of TSS content at all days of storage. Total Soluble Solids (TSS) increased with the increase in storage duration this increase in TSS content is due to the conversion of complex carbohydrates into simple sugars. This is correlated with hydrolytic changes in starch and conversion of starch to sugar being an important index of ripening process in mango

and other climacteric fruits and further hydrolysis decreased the TSS content during storage Kays[17] and Kittur *et al.*[18].

Titratable acidity of mango fruits irrespective of treatments decreased gradually with the progresses of storage time. The maximum titratable acidity were recorded in mango fruits coated with mustard oil at the 4th and 8th days of storage, respectively. On the other hand, the minimum titratable acidity were observed in the untreated control fruits at the same days of storage. The results of the experiment are supported by the findings of Mollah and Siddique[19]. They reported that titratable acidity was decreased gradually with the progresses of storage time.

There was a decreasing trend in relation to vitamin C content of fruit pulp during storage. It was also remarkable that vitamin C contents declined steadily up to the end of shelf life stage of storage. Absar *et al.*[20] supported the above results of vitamin C. The decreased in vitamin content with storage duration is attributed to the oxidation of ascorbic acid in to dehydro ascorbic acid by enzyme ascorbic acid oxidase. No fruits were found to be diseased till the 4th day of storage. Disease incidence was observed on the 6th day of storage. Overall, the oil coated fruits amply suppressed the disease growth during the period of investigation. The treatments, namely T_3 and T_7 performed the best in reducing postharvest spoilage of mangoes as compared to other treatments. There were no visible diseases until day 4 of storage. After that disease started to become visible and there were significant variation among the treatments. Results revealed that sesame oil coating performed the best in keeping the disease level down throughout the storage period followed by almond oil coating. At the 14th day of storage, the lowest disease severity was observed in fruits coated with sesame oil, whereas the level was the highest in the case of untreated control and olive oil coated fruits. The increase in percent disease severity observed in the present study is in support of the findings of Benitez *et al.*[21]. They stated that treated fruits showed lower disease severity than untreated fruits.

Shelf life is the basic quality of fruits which helps long marketing time and it is the most important aspect in loss reduction of fruits. The extension of shelf life of fruit has been one of the prime concerns of marketing throughout the record of history. The longest shelf life of 12 days was found in the paraffin coated fruits. Chitosan and almond oil coated fruits showed significant shelf life (10.67 days). Mustard oil also significantly extended shelf life of mango. Similar results were found by Salunkhe and Desai[22].

CONCLUSION

Shelf life varied significantly among the coating treatments and paraffin coating had the longest shelf life (12 days) followed by almond oil and chitosan (10.67 days). It was found that the postharvest coating treatments caused significant effects on peel color, firmness, moisture, dry matter content, weight loss, TSS content, disease incidence, severity, shelf life of mango and others characteristics of postharvest characteristics. Almond oil coating gave the best result in respect of reduction of disease severity and incidence and paraffin coating produced the best result, especially in relation to the reduction of weight loss and firmness which ultimately resulted in prolonged shelf life of mango.

SIGNIFICANCE STATEMENT

This study discovers to find out suitable concentration of chitosan to prolong shelf life and quality of mango. This study will help the researcher to uncover the critical area of postharvest loss of mango that many researchers were not able to explore. Thus, a new theory to investigate the physico-chemical and microbial attributes of mango as affected by coating materials, may be arrived at.

ACKNOWLEDGMENT

REFERENCES

1. FAO., 2012. FAO Statistical Yearbook 2012. Food and Agriculture Organization of the United Nations, Rome, Italy.
2. Shafique, M.Z., M. Ibrahim, M. Helali and S. K. Biswas, 2006. Studies on the physiological and biochemical composition of different mango cultivars at various maturity levels. Bangladesh J. Sci. Ind. Res., 41: 101-108.
3. Sauco, V.G., 2002. Magazine of chronica horticulturae. Int. Soc. Hort. Sci., 42: 14-17.

4. BBS., 2019. Year Book of Agricultural Statistics 2018. 30th Series. Bangladesh Bureau of Statistics, Statistics and Informatics Division (SID), Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh, pp: 36 and 44.

5. Rodov, V., S. Fishman, R. de la Asuncion, J. Peretz and S. Ben-Yehoshua, 1996. Modified Atmosphere Packaging (MAP) of 'tommy atkins' mango in perforated film. Acta Hortic., 455: 654-661.

6. Perez, K., J. Mercado and H. Soto-Valdez, 2004. Effect of storage temperature on the shelf life of Hass avocado (*Persea americana*). Food Sci. Technol. Int., 10: 73-75.

7. Hassan, M.K., B.L.D. Chowdhury and N. Akhther, 2010. Postharvest loss assessment: A study to formulate policy for postharvest loss reduction of fruits and vegetables and socio-economic uplift of the stakeholders. Final Report, PR No. 8/08. National Food Policy Capacity Strengthening Programme, pp: 1-188.

8. Subramanyam, H., S. Krishnamurthy and H.A.B. Parpia, 1975. Physiology and biochemistry of mango fruit. Adv. Food Res., 21: 223-305.

9. Hossain, M.A., 2016. Changes in ripening associated biochemical and enzymatic characteristics of late season mango (*Mangifera indica*, L.) of Bangladesh. J. Scient. Res., 8: 387-398.

10. Hossain, M.S. and A. Iqbal, 2014. Production and characterization of chitosan from shrimp waste. J. Bangladesh Agric. Univ., 12: 153-160.

11. Thenkabail, P.S. and J.G. Lyon, 2016. Hyperspectral Remote Sensing of Vegetation. CRC Press, New York, Pages: 228.

12. Ranganna, S., 1979. Manual Analysis of Fruit and Vegetable Products. Tata McGraw-Hill Publishing Company Limited, New Delhi, Pages: 112.

13. Onyeani, C.A. and N.A. Amusa, 2015. Incidence and severity of anthracnose in mango fruits and its control with plant extracts in South West Nigeria. Int. J. Agric. Res., 10: 33-43.

14. Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedure for Agricultural Research. 2nd Edn., John Willey and Sons, New York, Pages: 680.

15. Robinson, J.C., D.J. Nel and K. Eckstein, 1993. A field comparison of ten Cavendish sub-group banana cultivars and selections (Musa AAA) over four crop cycles in the subtroDics. J. Hortic. Sci., 68: 511-521.

16. Gowda, I.N.D. and A.G. Huddar, 2001. Studies on ripening changes in mango (*Mangifera indica* L.) fruits. J. Food Sci. Technol., 38: 135-137.

17. Kays, S.J., 1991. Postharvest Physiology of Perishable Plant Products. Vas Nostrand Rein Hold Book, London, pp: 149-316.

18. Kittur, F.S., N. Saroja, Habibunnisa and R.N. Tharanathan, 2001. Polysaccharide-based composite coating formulations for shelf-life extension of fresh banana and mango. Eur. Food Res. Technol., 213: 306-311.

19. Mollah, S. and M.A. Siddique, 1973. Studies on some mango varieties of Bangladesh. Bangladesh Hortic., 1: 16-24.

20. Absar, N., M.R. Karim and M.A.L. Amin, 1993. A comparative study on the changes in the physico-chemical composition of ten varieties of mango in Bangladesh at different stages of maturity. Bangladesh J. Agric. Res., 18: 201-208.

21. Benitez, M.M., A.L. Acedo Jr., P. Jitareerat and S. Kanlavanarat, 2006. Mango fruit softening response to postharvest heat treatment. Acta Hortic., 712: 811-816.

22. Salunkhe, D.K. and B.B. Desai, 1984. Postharvest Biotechnology of Fruits. 1st Edn., CRC Press, Boca Raton, Florida, Pages: 168.