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RESEARCH PAPER

Effect of Pre-storage Treatments on Quality and Shelf Life of Banana

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ABSTRACT

This study addresses the growing concern about food safety and explores alternative methods for preserving bananas of the Amritasagar variety. The experiment comprised thirteen treatments: T_1: Control, T_2: Tissue paper wrapping, T_3: Polythene wrapping, T_4: Lemongrass extract coating, T_5: Neem extract coating, T_6: Garlic extract coating, T_7: Mustard oil coating, T_8: Aloe gel coating, T_9: Hot water treatment, T_{10}: CaCl2 treatment, T_{11}: Earthen pot, T_{12}: CaCl2 and hot water treatment, T_{13}: Hot water and polythene wrapping treatment. After 9 days of storage, T_2 demonstrated the highest fruit firmness, measuring at 24.47 N, along with a dry matter content of 22.33%. Additionally, T_2 exhibited the longest shelf life, lasting for 21.33 days. Treatment T_{10} resulted in the highest weight loss (18.98%) and pH content (8.76) among the treatments. Treatment T_5 showed the highest titratable acidity (0.30%), while T_9 resulted in the highest (13.20%) total soluble solids (TSS) content. For anthocyanin content, T_{12} produced the highest level (90.54 μg/g), and T_8 exhibited the highest β-Carotene content (3.08 μg/g). The control treatment (T_1) showed the highest disease severity (76.19%) and disease incidence (87.11%), along with the lowest moisture content (54.0%) and titratable acidity (0.10%). Treatment T_{13} showed the lowest fruit firmness (7.33 N), dry matter content (9.33%), and β-Carotene content (0.90 μg/g). Treatment T_4 showed the lowest total soluble solids content (10.50%) and pH (6.54). Treatment T_2 exhibited the lowest anthocyanin content (36.1 μg/g) and disease severity (5.81%). The lowest weight loss (5.81%), disease incidence (5.07%), and shortest shelf life (6.67 days) were observed in T_6, T_8, and T_{12}, respectively. The study suggested tissue paper wrapping (T_2) as the most effective treatment for extending shelf life and maintaining postharvest quality based on longest shelf life, lowest disease severity, highest fruit firmness, and dry matter content.

Key words: Amritasagar, banana, pre-storage treatments, shelf life, quality

Introduction

Banana, scientifically known as *Musa sapientum* L. (Mohapatra *et al*. 2010), is a significant and long-standing fruit in tropical regions. Despite their relatively short postharvest life, bananas hold great commercial importance (Kamal *et al.* 2014). In Bangladesh, they dominate both in terms of cultivation area (121,384 acres) and production (810,347 MT), surpassing all other fruits (BBS 2020). The leading banana-producing countries globally include India, China, Ecuador, Brazil, and the Philippines (BBS 2014). Each year, approximately 80 million tons of bananas are cultivated worldwide (BBS 2015). In Bangladesh, bananas reign as the most popular fruit, contributing to 42% of the country's total fruit production and enjoying year-round availability (Kamal *et al*. 2016). This fruit holds a special place among Bangladeshi farmers due to its economic viability (BBS 2010). Bangladeshi farmers cultivate various banana varieties such as Amritasagar, Mehersager, Sabri, Jahaji, Singapuri, Agnishwar, Champa, Chini Champa, Kabuli, Basrai, Seeded banana, Anaji, and Kancha Kola (BBS 2014 & Akter *et al*. 2013). While banana cultivation is widespread throughout the country, certain regions benefit from favorable agroecological conditions and superior marketing facilities. Notable banana-growing areas include Rangamati, Barisal, Mymensingh, Bogra, Rangpur, Dinajpur, Noakhali, Faridpur, and Khulna. (Haque 1988).

Bananas have not only become an important cash and industrial crop worldwide but also play a vital role in enhancing human health due to their high nutritional value (Akter *et al*. 2013). From a nutritional standpoint, bananas offer high caloric value, carbohydrates, crude fiber, protein, fat, ash, phosphorus, iron, β-carotene, riboflavin, niacin, ascorbic acid, potassium, phosphorus, calcium, magnesium, and vitamin A. In Bangladesh, bananas hold a unique position as the only fruit crop available year-round with a higher consumption rate than any other fruit (Akter *et al*. 2013). Postharvest losses, encompassing both fruit quality and quantity, manifest at different stages throughout the postharvest lifespan of fruits, beginning from harvesting to consumption. Bananas, in particular, have a short shelf life at tropical ambient temperatures due to the changes associated with climacteric ripening, such as rapid softening, senescence spotting, off-odor development, anthracnose, crown rot disease incidence, and chilling injury when stored below 13 °C (Murmu *et al*. 2018). Crown rot is a major cause of significant losses in banana fruits, primarily caused by *Colletotrichum musae* and *Fusarium spp*., which attack mature bananas after they are harvested (Kamal *et al*. 2016).

The concept of bio-preservation, defined as a novel method for extending shelf life and enhancing food safety using natural or controlled microbiota and antimicrobial compounds, has emerged (Baldwin *et al*. 1995). Applying edible coatings on fresh bananas can create a modified internal atmosphere for the product and serve as an alternative to reduce both the quality and quantity losses, thus minimizing the major postharvest losses of bananas (Dhall 2013). Bagging or wrapping conditions have been shown to prolong shelf life, with unshielded green peels having a narrow pulp-to-peel weight ratio and maintaining optimal peeling conditions until the end of the shelf life (Prasad *et al*. 2015). Various countries around the world practice treatments with plant extract such as *aloe vera*, lemongrass, neem, garlic, etc. (Anjum *et al*. 2016). *Aloe vera* gel, in particular, has emerged as a promising bio-preservative and has been identified as a novel edible film coating with good antimicrobial properties (Brishti *et al*. 2013). Different parts of the neem plant, including leaves, flowers, and seeds, possess growth-regulating, fungicidal, and insecticidal properties (Helmy *et al*. 2007). Garlic extract, containing sulfur-containing compounds, has demonstrated antimicrobial activity against gram-positive and gram-negative bacteria (Naganawa *et al.* 1996). Postharvest calcium dips have been found to significantly increase calcium content in fruits compared to pre-harvest sprays, without causing fruit injury, depending on the type of salt and calcium concentration (Picchion *et al*. 1998). Hot water treatment has also been effective in controlling diseases in fruits (Feng *et al*. 1991).

This study aimed to examine the impact of bio-preservatives (garlic, *aloe vera*, neem, lemongrass and mustard oil), packaging materials (polythene, tissue paper and earthen pot), $CaCl_2$, and hot water regarding the quality after harvest and the shelf life of bananas throughout the storage period. The losses incurred after harvesting fruits and vegetables pose a major concern for economies heavily dependent on agriculture. In Bangladesh, these losses occur at various stages of the value chain, from harvesting to packaging, storage, transportation, retailing, and consumption. Limited knowledge and experience regarding different pre-storage treatments to extend the shelf life of bananas contribute to these losses. As a result of these losses in the postharvest stage, both the nutritional health of the population and the economies of developing countries are significantly impacted. In light of these considerations, this study aimed to explore the impact of diverse pre-storage treatments on the shelf life of bananas, while also assessing the quality parameters of the fruit throughout the storage duration.

Materials and Methods

The experiment was conducted at the Postharvest Laboratory of the Department of Horticulture, Patuakhali Science and Technology University (PSTU) in Patuakhali, Bangladesh. Fully matured green-colored banana fruits of the Amritasagar variety were selected as the experimental materials. These fruits were obtained from the Jalisha union of Dumki upazila, and harvested in the evening. Bananas selected for the study were of consistent size and shape, devoid of any visible defects, indications of disease, or signs of insect infestations. The fruits were handled with caution during transportation to the experimental site to prevent any injuries. The experiment followed a single-factor design and employed a completely randomized design (CRD) with three replications. The data collected on various parameters were analyzed using the MSTAT-C statistical package program (Michigan State University, USA). The means for all treatments were calculated, and analysis of variances (ANOVA) was performed using the F-test. To determine the significance of differences between mean values, the least significant difference (LSD) test was conducted at a 5% level of probability (Gomez & Gomez, 1984).

The experiment consists of thirteen treatments, T_1: Control (banana stored in room condition), T_2: Tissue paper wrapping (banana wrapped with tissue paper), T_3: Polythene wrapping (banana wrapped with polythene), T_4: Lemon grasses extract coating (banana dipped in fresh lemon grass extract for 2 minutes at 100% conc.), T_5: Neem extracts coating (banana dipped in fresh neem leaf extract for 2 minutes at 50% conc.), T_6: Garlic extracts coating (banana dipped in fresh garlic extract for 2 minutes at 100% conc.), T_7: Mustard oil coating (banana dipped in fresh mustard oil for 2 minutes at 100% conc.), T_8: *Aloe* gel coating (banana dipped in fresh *aloe* gel for 2 minutes at 100% conc.), T_9: Hot water treatment (55 ^{0}C for 1 minute), T_{10}: $CaCl_2$ treatment (banana dipped in $CaCl_2$ solution for 2 minutes at 4% conc.), T_{11}: Banana stored in an earthen pot (banana kept in a normal earthen pot with lid), T_{12}: $CaCl_2$ and Hot water treatment (55 ^{0}C for 1 minute and dipped in $CaCl_2$ solution for 2 minutes), T_{13}: Hot water and polythene wrapping treatment (55 ^{0}C for 1 minute and wrapped in polythene). Treatments were selected based on the findings of the previous studies for comparison. Fifteen randomly selected fruits were used for each treatment in this study.

Data was collected on the following parameters:

i. Fruit firmness, ii. Weight loss (%), iii. Moisture content (%), iv. Titratable acidity (%), v. Dry matter content (%), vi. Total soluble solids (% Brix), vii. pH, viii. Anthocyanin content (μg/g), ix. β-Carotene content (μg/g), x. Disease incidence (%) xi. Disease severity (%) and xii. Shelf life.

Fruit firmness was measured using a digital fruit firmness tester (Model GY-802) and was expressed in Newton (N). To calculate weight loss, five bananas from each replication of every treatment were initially weighed and weighed again on the day of data collection. Weight loss was determined using the following formula:

$$WL\,(\%) = \frac{IW - FW}{IW} \times 100$$

Where, WL (%) = Percent total weight loss, IW = Initial weight of the fruits (g), FW = Final weight of the fruits (g).

To assess the moisture content, ten grams of banana pulp from each treatment and replication were weighed using an analytical balance (Model no. HR300i) and placed in a petri dish. The petridish was then put in an electric oven (Model no. Memmert U40) at 55 ℃ for 72 hours until a constant weight was achieved. After cooling, the sample was reweighed, and the moisture content of the banana pulp was calculated using the following formula:

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

Where, IW = Initial weight of pulp (g), FW = Final weight of oven-dried pulp (g).

Titratable acidity (TA) was estimated according to the method of Ranganna (1977) and expressed as a percentage. The percentage of dry matter content in the banana pulp was calculated using the data obtained during moisture estimation with the following formula: Percent dry matter = (100 – percent moisture content). The total soluble solids (TSS) of banana juice were estimated by using a digital refractometer (BOECO, Germany) and expressed as % Brix. The p^H was estimated by using a glass electrode p^H meter (GLP 21, Crison, Barcelona, and EEC). The total anthocyanin content of the peel was determined by the method of Sims and Gamon (2002) and calculated as µg/g. The β-Carotene in bananas was determined according to the method of Nagata & Yamashita (1992) and measured as µg/g.

Disease incidence refers to the percentage of fruits infected with the disease, measured by calculating the proportion of infected fruits. Visual identification of symptoms was employed to recognize the diseased fruits, and the disease incidence (DI) was determined using the following formula:

$$DI\,(\%) = \frac{\text{Number of infected fruits}}{\text{Total number of fruits under study}} \times 100$$

Disease severity represents the percent diseased portion of infected banana fruit. The infected fruits of each replication of each treatment were selected to determine the percent fruit area infected and were measured using a centimeter scale. In this study, data on the physico-chemical properties of bananas were collected at 3-day intervals up to the 9th day of storage, coinciding with the conclusion of the shelf life for some treatments. The shelf life of banana fruits was determined by measuring the duration between storage when the peel was green and the point when the fruits achieved full ripeness with a yellow peel, while still retaining optimal marketing and eating qualities (Figure 1).

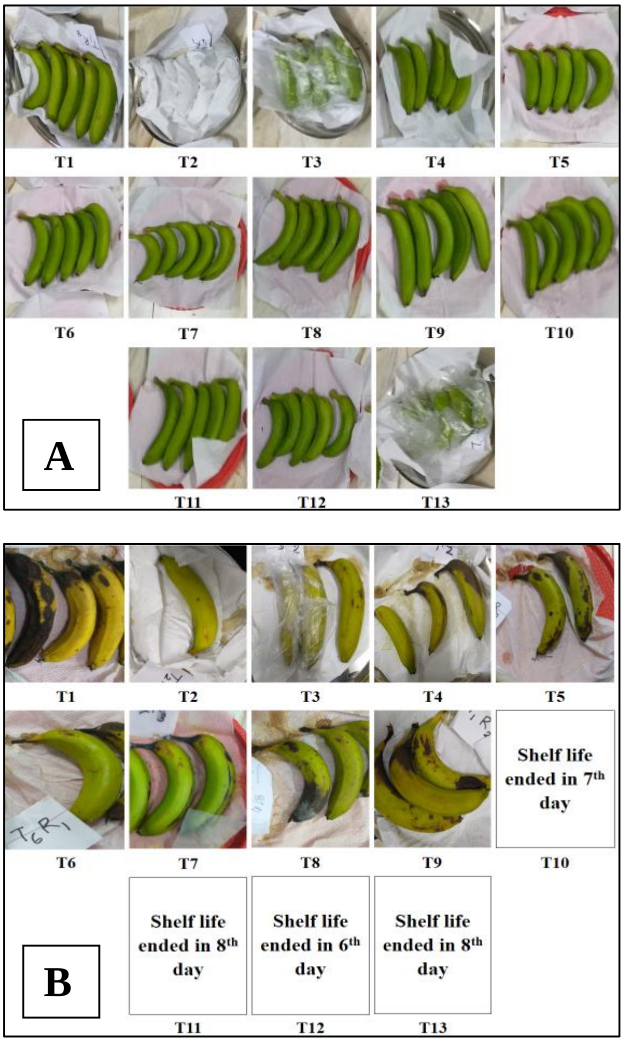

Figure 1: Storage of banana fruit during the study. **A**) At the beginning of study **B**) At 12th days after storage (DAS). T_1: Control, T_2: Tissue paper wrapping, T_3: Polythene wrapping, T_4: Lemon grasses extract coating, T_5: Neem extracts coating, T_6: Garlic extracts coating, T_7: Mustard oil coating, T_8: *Aloe* gel coating, T_9: Hot water treatment, T_{10}: $CaCl_2$ (banana dipped in $CaCl_2$ solution), T_{11}: Earthen pot, T_{12}: $CaCl_2$ + Hot water treatment, T_{13}: Hot water treatment + Polythene wrapping.

Results and Discussion

Fruit firmness (N)

Various pre-storage treatments had a significant ($p<0.05$) impact on the firmness of banana fruits. During the entire storage period of the experiment, the firmness of banana fruits declined in all treatments (Figure 2). Wrapping the fruits with tissue paper (T_2) notably delayed the loss of firmness during storage. The tissue paper-wrapped fruits (T_2) exhibited the highest firmness value (24.47 N), while the lowest firmness (7.33 N) was observed in fruits subjected to the hot water and polythene wrapping treatment (T_{13}) on the 9th day of storage. Wrapping the banana fruits with tissue paper might have conferred resistance against compositional changes in cell walls and moisture loss, resulting in reduced softening or increased firmness (Mohebbi *et al.*

2014). Generally, fruit softening intensifies as ripening progresses due to the hydrolysis or depolymerization of pectin substances (Yaman & Bayoindirli 2002 and Willats *et al*. 2001).

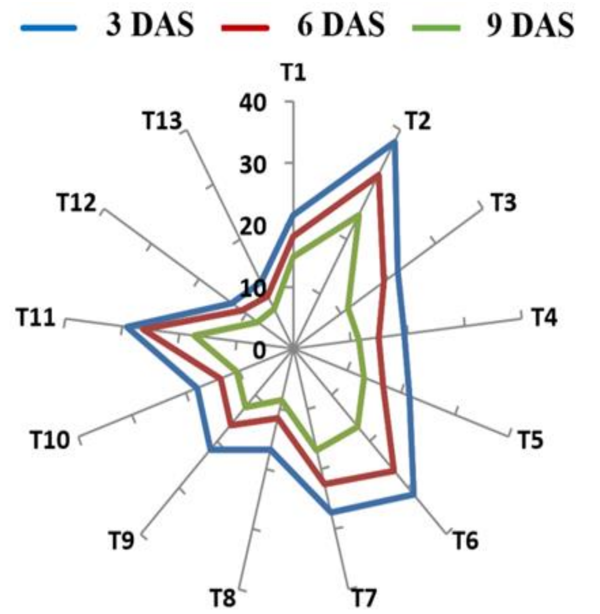

Figure 2: Changes of fruit firmness at different days after storage (DAS).

T_1: Control, T_2: Tissue paper wrapping, T_3: Polythene wrapping, T_4: Lemon grasses extract coating, T_5: Neem extracts coating, T_6: Garlic extracts coating, T_7: Mustard oil coating, T_8: *Aloe* gel coating, T_9: Hot water treatments, T_{10}: $CaCl_2$ (banana dipped in $CaCl_2$ solution), T_{11}: Earthen pot, T_{12}: $CaCl_2$ + Hot water treatment, T_{13}: Hot water treatment + Polythene wrapping.

Weight loss of banana

Variations in weight loss were observed among the various pre-storage treatments applied to banana fruits, showing a significant difference (*$p<0.05$*). Generally, weight loss exhibited a decreasing trend as the storage period increased (Figure 3). The highest weight loss value (18.98%) was observed in fruits treated with $CaCl_2$ (T_{10}), while the lowest value (4.5%) was recorded for banana fruits coated with garlic extract (T_2) after the 9th day of storage. The diminished weight loss observed in fruits coated with garlic extract, containing sulfur-containing compounds, may be attributed to the obstruction of stomata and guard cells, subsequently decelerating active metabolic processes and respiration.

Additionally, the semi-permeable effect of the coating may have contributed to reduced weight loss by regulating moisture loss, respiration, and solute movement across the membrane. Previous studies by Ashwini and Desai (2018) on mango, Mahmoud *et al.* (2018) on pear, Kamel (2014) on Valencia orange, and Armanious (2014) on Thompson seedless grapevines have also reported a decreasing trend in weight loss during storage when treated with garlic or onion extracts.

Moisture content

The moisture content of banana fruits was significantly reduced across all treatments during the shelf-life study (Table 1). While the pre-storage treatments showed higher moisture content values compared to the control group, a significant (*$p<0.05$*) difference was observed among the pre-storage treatments. This highlights the water barrier effect of coatings, wrapping materials, and other treatments, as well as the interactions formed with the fruit surface (influenced by the type of coating),

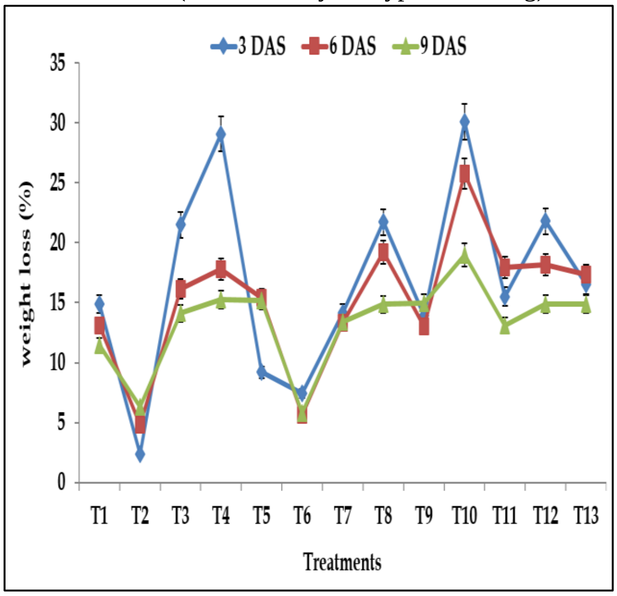

Figure 3: Weight loss of banana at different days after storage (DAS).

T_1: Control, T_2: Tissue paper wrapping, T_3: Polythene wrapping, T_4: Lemon grasses extract coating, T_5: Neem extracts coating, T_6: Garlic extracts coating, T_7: Mustard oil coating, T_8: *Aloe* gel coating, T_9: Hot water treatments, T_{10}: $CaCl_2$ (banana dipped in $CaCl_2$ solution), T_{11}: Earthen pot, T_{12}: $CaCl_2$ + Hot water treatment, T_{13}: Hot water treatment + Polythene wrapping. Vertical bars represent the standard error of the mean.

which play a crucial role in determining the effectiveness of the coating in controlling water migration (Sarabandi *et al*. 2017, 2018). This can be attributed to the treatments' lower permeability to water vapor compared to the control group. The highest moisture content (73.33%) was observed in fruits treated with hot water and polythene wrapping (T_{13}), while the lowest moisture content (54.0%) was found in the control treatment (T_1) after the 9th day of storage.

Titratable acidity (TA)

The titratable acidity (TA) of banana fruits was significantly (*$p<0.05$*) influenced by both the pre-storage treatments at different storage durations, as shown in Table 1. The application of pre-storage treatments resulted in higher TA levels in the bananas. Among all the pre-storage treatments, neem extract-coated fruits (T_5) exhibited the highest TA value (0.30%), while the control group (T_1), tissue paper-wrapped fruits (T_2), mustard oil-treated fruits (T_7), fruits treated with a combination of $CaCl_2$ and hot water (T_{12}), and fruits treated with a combination of hot water and polythene wrapping (T_{13}) had the lowest TA value (0.10%) after 9 days of storage. The higher TA in neem extract-coated fruits can be attributed to reduced respiration, which ultimately prevents the oxidation of organic acids. Conversely, the swift decline in titratable acidity (TA) in uncoated fruits could be attributed to heightened respiration and the oxidation of organic acids. Similarly, Rashid (2013) reported the highest titratable acidity in neem extract + perforated polythene-treated banana fruits after 12 days of storage.

Table 1: Effects of different pre-storage treatments on moisture content and titratable acidity of banana on different days after storage (DAS)

Treatments	Moisture Content (%)			Titratable Acidity (%)		
	3 DAS	6 DAS	9 DAS	3 DAS	6 DAS	9 DAS
T_1	70.33	64.67	54.00	0.10	0.20	0.10
T_2	72.00	73.00	71.67	0.13	0.10	0.10
T_3	73.00	72.00	71.00	0.20	0.13	0.13
T_4	72.00	71.33	70.00	0.20	0.20	0.23
T_5	75.33	72.67	70.67	0.17	0.17	0.30
T_6	73.33	71.00	69.33	0.13	0.20	0.17
T_7	75.00	73.00	71.67	0.20	0.20	0.10
T_8	74.67	72.67	70.33	0.17	0.23	0.20
T_9	76.00	71.00	67.00	0.17	0.23	0.20
T_{10}	74.00	72.33	69.33	0.40	0.30	0.27
T_{11}	75.00	71.67	69.00	0.23	0.20	0.20
T_{12}	73.67	68.33	65.67	0.17	0.17	0.10
T_{13}	79.00	76.67	73.33	0.20	0.20	0.10
Level of significance	*	**	**	**	**	**
LSD at 5%	3.85	2.56	1.98	0.07	0.05	0.05
CV (%)	3.14	2.17	1.75	23.11	18.98	19.12

** Significant at 1% level of probability, DAS = Days after storage, CV= Co-efficient of Variation.T_1: Control, T_2: Tissue paper wrapping, T_3: Polythene wrapping, T_4: Lemon grasses extract coating, T_5: Neem extracts coating, T_6: Garlic extracts coating, T_7: Mustard oil coating, T_8: *Aloe* gel coating, T_9: Hot water treatments, T_{10}: $CaCl_2$ (banana dipped in $CaCl_2$ solution), T_{11}: Earthen pot, T_{12}: $CaCl_2$ + Hot water treatment, T_{13}: Hot water treatment + Polythene wrapping.

Dry matter content

The dry matter content of bananas was significantly influenced ($p<0.05$) by the various pre-storage treatments. The dry matter content of bananas decreased under all pre-storage treatments throughout the storage period (Figure 4). After 9 days of storage, bananas wrapped in tissue paper (T_2) exhibited the highest dry matter content (22.33%), while the lowest dry matter content (9.33%) was recorded in bananas treated with a combination of hot water and polythene wrapping (T_{13}). Hailu *et al.* (2014) reported that packing banana fruits with dried banana leaves helped maintain a higher dry matter content compared to the control group (no packing). Increased rates of respiration result in a decrease in the proportion of fruit dry matter (Dadzie & Orchard 1997). Bananas with longer ripening time and firmer pulp tend to have higher dry matter content. The dry matter content is closely related to storage life and fruit quality, with higher dry matter content indicating better eating quality (Dadzie & Orchard 1997).

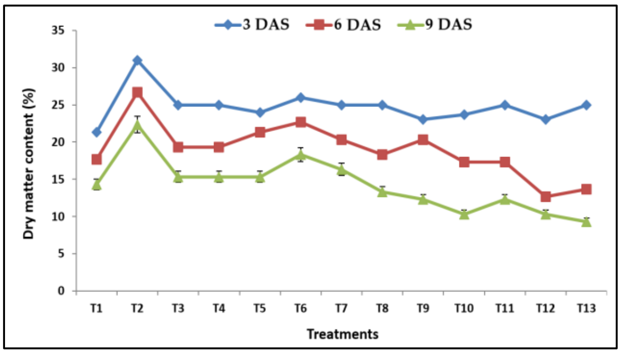

Figure 4: Dry matter content (%) of banana at different days after storage (DAS).

T_1: Control, T_2: Tissue paper wrapping, T_3: Polythene wrapping, T_4: Lemon grasses extract coating, T_5: Neem extracts coating, T_6: Garlic extracts coating, T_7: Mustard oil coating, T_8: *Aloe* gel coating, T_9: Hot water treatments, T_{10}: $CaCl_2$ (banana dipped in $CaCl_2$ solution), T_{11}: Earthen pot, T_{12}: $CaCl_2$ + Hot water treatment, T_{13}: Hot water treatment + Polythene wrapping. Vertical bars represent the standard error of the mean.

Total soluble solids (TSS) content

A significant ($p<0.05$) distinction was observed in the total soluble solids (TSS) content among the different pre-storage treatments during the storage period, as shown in Figure 5. The TSS content increased as the storage period progressed in this study. The highest TSS content (13.20%) was observed in banana fruits treated with hot water (T_9), while the lowest TSS content (10.50%) was observed in banana fruits coated with lemon grass extract (T_4) after nine days of storage. The content of total soluble solids (TSS), along with titratable acidity (TA), is pivotal in determining the flavor and nutritional quality of fruits. The total soluble solids increase from the mature breaker green stage to the yellow stage, indicating the conversion of carbohydrates into soluble sugars through hydrolysis (Reyes *et al*. 1998; Waskar *et al*. 1999). Similar increases in TSS content have been observed in banana fruits treated with hot water (Kaka *et al*. 2019), peaches (Sadiq *et al*. 2016), and mangoes (Angasu *et al*. 2014). Earthen pot, T_{12}: $CaCl_2$ + Hot water treatment, T_{13}: Hot water treatment + Polythene wrapping. Vertical bars represent the standard error of the mean.

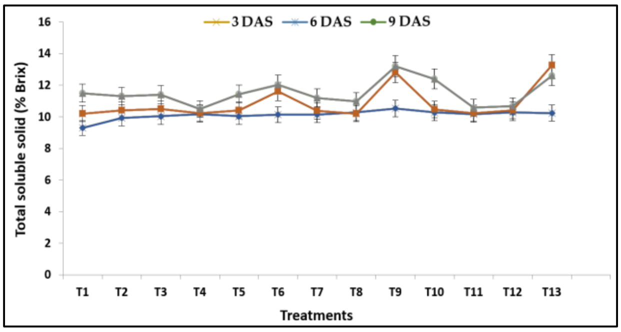

Figure 5: Total soluble solid (% Brix) of banana at different days after storage (DAS).

T_1: Control, T_2: Tissue paper wrapping, T_3: Polythene wrapping, T_4: Lemon grasses extract coating, T_5: Neem extracts coating, T_6: Garlic extracts coating, T_7: Mustard oil coating, T_8: *Aloe* gel coating, T_9: Hot water treatments, T_{10}: $CaCl_2$ (banana dipped in $CaCl_2$ solution), T_{11}: Earthen pot, T_{12}:

$CaCl_2$ + Hot water treatment, T_{13}: Hot water treatment + Polythene wrapping. Vertical bars represent the standard error of the mean.

p^H^

The pH of banana fruits exhibited a significant ($p<0.05$) increase as the storage period advanced, except for fruits coated with lemon grass extract, as shown in Table 2. On the 9th day of storage, fruits treated with $CaCl_2$ (T_{10}) exhibited the highest pH value (8.76), while those coated with lemongrass extract (T_4) recorded the lowest pH value (6.54). Throughout the maturation and ripening process, the pH of fruits changes, increasing from the mature breaker green stage to the yellow ripe stage as the storage period progresses in this study. Different pre-storage treatments controlled enzymatic activities and senescence (maturity and ripening), ultimately influencing the acid levels (Khodaei *et al*. 2021). Studies by Sajid *et al*. (2019) on pears, Sabir *et al*. (2004) on apples, and Hayat and Rathore (2003) on apple fruits have reported an increase in acidity with the application of calcium chloride.

Table 2: Effects of different pre-storage treatments on pH and anthocyanin content of banana at different days after storage (DAS)

Treatments	pH			Anthocyanin (µg/g)		
	3 DAS	6 DAS	9 DAS	3 DAS	6 DAS	9 DAS
T_1	5.80	5.70	6.66	32.87	54.18	63.76
T_2	6.65	7.04	7.65	8.46	25.49	36.11
T_3	6.44	6.17	7.55	24.78	44.94	55.19
T_4	7.38	6.90	6.54	48.08	76.81	82.22
T_5	6.41	6.64	7.61	15.30	50.78	72.54
T_6	6.16	7.73	7.77	10.50	30.96	39.69
T_7	6.69	6.62	7.65	19.08	36.03	45.78
T_8	5.79	6.44	7.56	30.67	51.13	64.04
T_9	5.16	6.47	7.54	8.63	30.51	50.15
T_{10}	5.45	6.03	8.76	23.47	48.49	73.01
T_{11}	7.45	6.25	7.77	46.05	62.07	68.13
T_{12}	5.53	6.33	7.61	77.95	86.07	90.54
T_{13}	5.29	6.21	7.67	60.49	75.30	79.97
Level of significance	**	**	**	**	**	**
LSD at 5%	0.05	0.38	0.28	1.39	2.49	2.61
CV (%)	0.09	3.55	2.23	2.68	2.92	2.50

** Significant at 1% level of probability, DAS = Days after storage, CV= Co-efficient of Variation.T_1: Control, T_2: Tissue paper wrapping, T_3: Polythene wrapping, T_4: Lemon grasses extract coating, T_5: Neem extracts coating, T_6: Garlic extracts coating, T_7: Mustard oil coating, T_8: *Aloe* gel coating, T_9: Hot water treatments, T_{10}: $CaCl_2$ (banana dipped in $CaCl_2$ solution), T_{11}: Earthen pot, T_{12}: $CaCl_2$ + Hot water treatment, T_{13}: Hot water treatment + Polythene wrapping.

Anthocyanin content

A significant ($p<0.05$) difference in the total anthocyanin content among the different treatments was observed until day 9. It can be noted that all samples showed an increase in total anthocyanin content with the progression of storage time, as shown in Table 2. However, banana fruits treated with a combination of $CaCl_2$ and hot water (T_{12}) exhibited a significantly higher amount of total anthocyanin content compared to the other treatments on day 9. The anthocyanin content in the remaining treatments ranged from 82.22 µg/g to 36.11 µg/g. This result can be attributed to the fact that pre-storage treatments of fruits help to prevent senescence and disruptions in anthocyanin synthesis (Wang *et al*. 2013). Aghdam *et al*. (2013) reported an increase in anthocyanin content when sweet cherries were treated with 80 mM $CaCl_2$. The total anthocyanin content is important for the appearance and maturity of fruits (Wang *et al*. 2013).

β-Carotene content

The β-carotene content of bananas exhibited significant ($p<0.05$) variations among the different pre-storage treatments, as shown in Figure 6. On the 9th day of storage, bananas coated with *aloe* gel (T_8) exhibited the highest β-carotene content (3.08 µg/g), whereas those treated with a combination of hot water and polythene wrapping (T_{13}) showed the lowest β-carotene content (0.90 µg/g). This difference may be attributed to the early onset of respiration and ethylene production. Different postharvest treatments resulted in varying periods for the successive peel color development in bananas, and the commencement of ripening can vary for various reasons (Hossain *et al*. 2015).

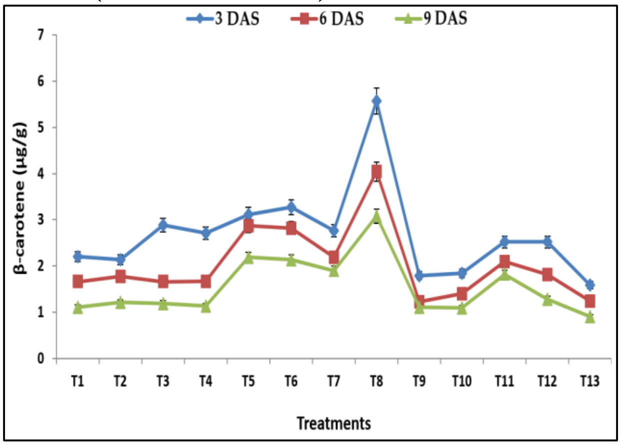

Figure 6: β-Carotene content (µg/g) of banana at different days after storage (DAS).

T_1: Control, T_2: Tissue paper wrapping, T_3: Polythene wrapping, T_4: Lemon grasses extract coating, T_5: Neem extracts coating, T_6: Garlic extracts coating, T_7: Mustard oil coating, T_8: *Aloe* gel coating, T_9: Hot water treatments, T_{10}:

$CaCl_2$ (banana dipped in $CaCl_2$ solution), T_{11}: Earthen pot, T_{12}: $CaCl_2$ + Hot water treatment, T_{13}: Hot water treatment + Polythene wrapping. Vertical bars represent the standard error of the mean.

Diseases incidence

Significant (*p<0.05*) variations in disease incidence of bananas during storage were observed among the different pre-storage treatments, as depicted in Figure 7. By the 9th day of storage, disease incidence became noticeable. The control group (T_1) exhibited the highest disease incidence (87.11%), while the lowest incidence (5.07%) was observed in bananas coated with *aloe* gel (T_8). The variation in disease incidence can be attributed to the protective layer created by *aloe* gel, serving as a barrier against oxygen and moisture from the air. Additionally, *aloe* gel contains antibacterial and antifungal compounds that inhibit the growth of microorganisms responsible for food-borne diseases. Plant extracts with antimicrobial properties can prevent diseases either by directly acting on the fungus or by inducing defense responses through the activation of antioxidant enzymes such as superoxide dismutase, lipoxygenase, and catalase (Murmu *et al*. 2013). Brishti *et al*. (2013) reported a disease incidence of only 27% at the end of a 7-day storage period when papayas were coated with *aloe* gel, compared to 100% disease incidence in uncoated fruits. Furthermore, the application of *aloe vera* gel coating has been shown to preserve fruit quality by reducing fungal decay in table grapes (Valverde *et al*. 2005) and sweet cherries (Asghari *et al*. 2013).

Diseases severity

Disease severity showed a significant (*p<0.05*) decrease over time in all treatments, and the pre-storage treatments played a role in reducing disease severity in bananas, as shown in Figure 8. Particularly, on the 9th day of storage, banana fruits wrapped with tissue paper (T_2) exhibited the lowest disease severity (5.81%), whereas the control treatment (T_1) showed the highest severity (76.19%). This difference in disease severity could be attributed to the inhibition of microbial activity by all the pre-storage treatments compared to the control group.

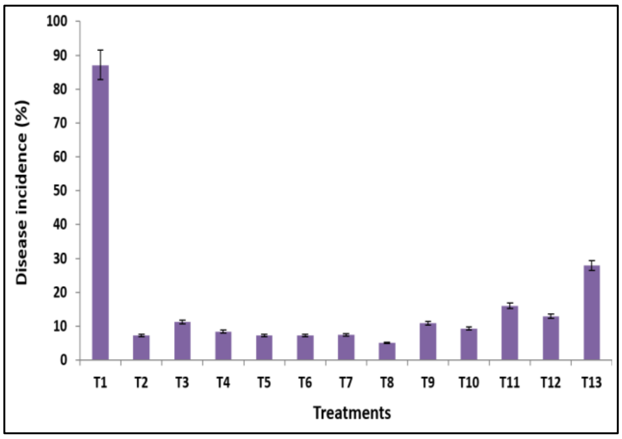

Figure 7: Disease incidence of banana at 9 days after storage (DAS).

T_1: Control, T_2: Tissue paper wrapping, T_3: Polythene wrapping, T_4: Lemon grasses extract coating, T_5: Neem extracts coating, T_6: Garlic extracts coating, T_7: Mustard oil coating, T_8: *Aloe* gel coating, T_9: Hot water treatments, T_{10}: $CaCl_2$ (banana dipped in $CaCl_2$ solution), T_{11}: Earthen pot, T_{12}: $CaCl_2$ + Hot water treatment, T_{13}: Hot water treatment + Polythene wrapping. Vertical bars represent the standard error of the mean.

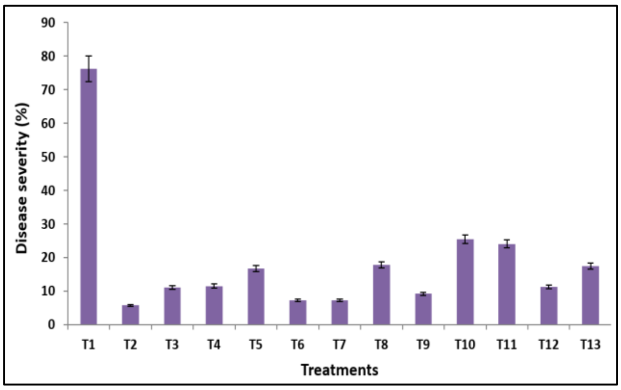

Figure 8: Disease severity of banana at 9 days after storage (DAS).

T_1: Control, T_2: Tissue paper wrapping, T_3: Polythene wrapping, T_4: Lemon grasses extract coating, T_5: Neem extracts coating, T_6: Garlic extracts coating, T_7: Mustard oil coating, T_8: *Aloe* gel coating, T_9: Hot water treatments, T_{10}: $CaCl_2$ (banana dipped in $CaCl_2$ solution), T_{11}: Earthen pot, T_{12}: $CaCl_2$ + Hot water treatment, T_{13}: Hot water treatment + Polythene wrapping. Vertical bars represent the standard error of the mean.

Shelf life

The shelf life of banana fruits was significantly (*p<0.05*) influenced by the various pre-storage treatments, as illustrated in Figure 9. Banana fruits wrapped with tissue paper (T_2) exhibited the longest shelf life (21.33 days) during the study, followed by garlic extract coating (20 days). Conversely, the shortest shelf life (6.67 days) was observed in bananas treated with a combination of $CaCl_2$ and hot water (T_{12}) treatment. This result can be attributed to the fact that wrapping banana fruits with tissue paper reduces ethylene release, lowers respiration rates, and consequently slows down the process of maturation, thereby extending the shelf life. The combination of a cool chamber and tissue paper has been found to significantly improve the quality and storage properties of banana fruits (Prasad *et al*. 2015).

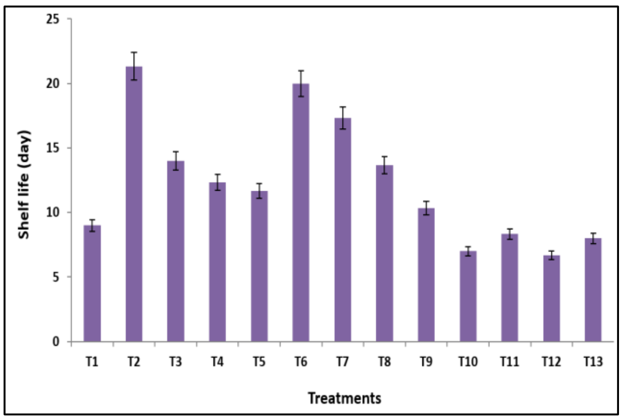

Figure 9: Shelf life of banana stored under different pre-storage treatments.

T_1: Control, T_2: Tissue paper wrapping, T_3: Polythene wrapping, T_4: Lemon grasses extract coating, T_5: Neem extracts coating, T_6: Garlic extracts coating, T_7: Mustard oil coating, T_8: *Aloe* gel coating, T_9: Hot water treatments, T_{10}: $CaCl_2$ (banana dipped in $CaCl_2$ solution), T_{11}: Earthen pot, T_{12}: $CaCl_2$ + Hot water treatment, T_{13}: Hot water treatment + Polythene wrapping. Vertical bars represent the standard error of the mean.

Conclusion

The pre-storage treatments applied to banana fruits, including tissue paper wrapping, polythene wrapping, lemon grass extract coating, neem extract coating, garlic extract coating, mustard oil coating, *aloe* gel coating, hot water treatment, $CaCl_2$ treatment, earthen pot storage, $CaCl_2$ + hot water treatment, and hot water treatment + polythene wrapping, demonstrated significant reductions in moisture content, disease incidence, and disease severity when compared to the control. These diverse pre-storage treatments had a positive impact on preserving fruit firmness, pH, total soluble solids contents, anthocyanin contents, and extending the shelf life. Among the treatments, the wrapping of banana fruits with tissue paper (T_2) was found to be the most effective pre-storage treatment in terms of shelf life extension, minimal disease severity, highest fruit firmness, and dry matter content in this study. These findings validate the potential of the aforementioned pre-storage treatments for enhancing the shelf life and quality of bananas.

References

Aghdam MS, Dokhanieh AY, Hassanpour H, Rezapour, Fard J (2013) Enhancement of antioxidant capacity of cornelian cherry (Cornus mas) fruit by postharvest calcium treatment. *Scientia Horticulturae* **161**: 160–64. doi:10.1016/j.scienta. 2013.07.006

Akter H, Hassan MK, Rabbani MG, Mahmud AA (2013) Effects of variety and postharvest treatments on shelf life and quality of Banana. *Journal of Environmental Science and Natural Resources* **6(2)**: 163–175.doi: https://doi.org/10.3329/jesnr.v6i2.22 113

Angasu ON, Dessalgne OG, Tadesse TN (2014) Effect of Hot Water Treatment on Quality and Incidence of Postharvest Disease of Mango (*Mangifera indicia* L.) Fruits. *Asian Journal of Plant Sciences* **13(2)**: 87–92. doi: 10.3923/ajps.2014.87.92

Anjum MA, Ahmed N, Babita CH, Gupta P (2016) Plant extracts in post-harvest disease management of fruits and vegetables-a review. *Journal of Food Processing and Technology* **7(6)**: 1–5. doi:10.4172/ 2157-7110.1000592

Armanious MKHU (2014) The synergistic effect of spraying some plant extracts with some macro and micro Nutrients of Thompson seedless grapevines. *International Journal of Plant & Soil Science* **3(10)**: 1290–1301. doi: 10.9734/IJPSS/2014/8610

Asghari M, Khalili H, Rasmi Y, Mohammad zadeh A (2013) “Influence of postharvest nitric oxide and *Aloe vera* gel application on sweet cherry quality indices and storage life,” *International Journal of Agronomy and Plant Production* **4(9)**: 2393–2398.

Ashwini M, Desai N (2018) Biopreservative effect of plant extracts on the shelf life of mango cv Raspuri. *Journal of Pharmacognosy and Phytochemisty* **7(6)**: 2245–2248.

Baldwin EA, Nisperos MO, Baker RA (1995) ″Edible coatings for lightly processed fruits and vegetables ″, *Horticultural Science* **30(1)**: 30–35. doi:10.21273/HORTSCI.30.1.35

BBS (2020) Ministry of Agriculture, Government of the people´s Republic of Bangladesh, Dhaka, Bangladesh. pp. 1–658.

BBS (2015) Ministry of Agriculture, Government of the people´s Republic of Bangladesh, Dhaka, Bangladesh. pp. 1–586.

BBS (2015) Small Area Atlas, Mouzas and Mohallahs of Bogra District. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government of the People’s Republic of Bangladesh, Dhaka. pp. 1–71.

BBS (2014) “Report on the productivity survey of Banana crop–2013” under Productivity Assessment Survey of Different Agricultural Crops Programme, Bangladesh Bureau of Statistics (BBS), Statistics and Informatics Division (SID), Ministry of Planning. August, 2014. pp. 1–134.

BBS (2010) Yearbook of Agricultural statistics of Bangladesh. Bangladesh bureau of Statistics Division, Ministry of Planning, Government of People’s Republic of Bangladesh. pp. 1–377.

Brishti FH, Misir J, Sarker A (2013) “Effect of Biopreservatives on storage life of Papaya fruit (Carica Papaya L.)”, *Intermational Journal of Food Studies* **2(1)**: 126–136.

Dadzie BK, Orchard JE (1997) Routine postharvest screening of banana/plantain hybrids criteria and methods. International network for banana and plantain (Inibap), Technical Guidelines. Rome, Italy.

Dhall RK (2013) Advances in edible coatings for fresh fruits and vegetables: a review. *Critical reviews in food science and nutrition* **53(5)**: 435–450. doi:10.1080/10408398.2010.541568

Feng SQ, Chen XY, Zhou ST (1991) Effect of postharvest treatments on physiochemical characters of mango fruits (cv, Bullock's heart) during storage. *Annual Agricultural Science* **44(2)**: 705–716.

Gomez KA, Gomez AA (1984) Statistical Procedure for Agricultural Research (2nd Edn.), John Willey and Sons, Now York. pp. 28–92.

Hailu M, Seyoum Workneh T, Belew D (2014) Effect of packaging materials on shelf life and quality of banana cultivars (*Musa spp*.). *Journal of Food Science and Technology* **51(11)**: 2947–2963. doi:10.1007/s13197-012-0826-5

Haque MA (1988) Kalar Bagan (in Bengali). Banana Research Project, Bangladesh Agricultural University, Mymensingh. pp. 1–4.

Hayat I, Masud T, Rathore HA (2003) Effect of coating and wrapping materials on the shelf life of apple (*Malus domestica* cv. Borkh). *Inter Journal of Food Safety* **5(5)**: 24–34.

Helmy WA, Amer H, El-Shayeb NMA (2007) Biological and anti-microbial activities of aqueous extracts from neem tree (*Azadirachta indica* A. Juss., *Meliaceae*). *Journal of Applied Sciences and Research* **3(10)**: 1050–1055.

Hossain MZ, Hassan MK, Arifuzzaman SM, Sayeeduzzaman, Hussain J (2015) Effects of Different Plant Extracts on the Extension of Shelf Life of Banana. *International Journal of Business Social and Scientific Research* **3(4)**: 204–218. Retrieve from http://www.ijbssr.com/currentissue view/14013108

Kaka, Ajeet Kumar *et al*. (2019) Effect of hot water treatments and storage period on the quality attributes of banana (*Musa sp*.) fruit. *Pure and Applied Biology*

(PAB) 8(1): 363–371. http://dx.doi.org/10.19045/ bspab.2018.700195

Kamal MS, Ali MA, Alam MF (2016) Socio-economic Status and Problems of Banana Growers in Bangladesh, *International Journal of Natural and Social Sciences* **3(1)**: 94–99.

Kamal MS, Ali MA, Alam MF (2014) Socio-economic status and problems of banana growers in Bangladesh. *International Journal of Natural and Social Sciences* **1(2)**: 91–99.

Kamel HM (2014) Impact of garlic oil, seasweed extract and imazalil on keeping quality of Valencia orange fruits during cold storage. *Journal of Horticultural Science and Ornamental Plants* **6 (3)**: 116–125. doi: 10.5829/idosi.jhsop.2014.6.3.114

Khodaei D, Hamidi-esfahani Z, Rahmati E (2021) Effect of edible coatings on the shelf-life of fresh strawberries : A comparative study using TOPSIS-Shannon entropy method. *NFS Journal* ***23***: 17–23. https://doi.org/10.1016/j.nfs.2021.02.003

Mahmoud GA, Ahmed ST, Abbas SM, Soliman SA (2018)Effect of Garlic and Onion Extracts as a Preharvest Applications on the Postharvest Quality and Oxidative Enzyme Activity of Pearfruit During Cold Storage. *Journal of Biology, Chemistry and Environmental Science* **13(4)**: 329–356.

Mohapatra D, Mishra S, Sutar N (2010) Banana post-harvest practices: current status and future prospects-a review. *Agricultural Reviews* **31(1)**: 56– 62.

Mohebbi M, Hasanpour N, Ansarifar E, Amiryousefi MR (2014) "Physicochemical Properties of Bell Pepper and Kinetics of Its Color Change Influenced by *Aloe vera* and Gum Tragacanth Coatings during Storage at Different Temperatures," *Journal of Food Processing and Preservation* **38(2)**: 684–693. doi:10.1111/jfpp. 12018

Murmu SB, Mishra HN (2018) Post-harvest shelf-life of banana and guava: Mechanisms of common degradation problems and emerging counteracting strategies. *Innovative Food Science & Emerging Technologies* **49(1)**: 20–30. doi:10.1016/j.ifset. 2018.07.011

Naganawa R, Iwata N, Ishikawa K, Fukuda H, Fujino T, Suzuki A (1996) Inhibitition of microbial growth by ajoene, a sulfur-containing compound derived from garlic. *Applied and environmental microbiology* **62(11)**: 4238–4242.

Nagata M, Yamashita I (1992) Simple method for simultaneous determination of chlorophyll and carotenoids in tomato fruits. *Nippon Shokuhin Kogyo Gakkaishi* **39(10)**: 925–928.

Picchion GA, Watada AE, Conway WS, Whitaker BD, Sams CE (1998) Postharvest calcium infiltration delays membrane lipid catabolism in apple fruit. *Journal of Agricultural and Food Chemistry* **46(7)**: 2452–2457. https://doi.org/10.1021/jf971083e

Prasad R, Ram RB, Kumar V, Rajvanshi SK (2015) Study on Effect of Different Packaging Materials on Shelf Life of Banana (*Musa paradisiaca* L .) cv . Harichal Under Different Conditions. *International Journal of Pure and Applied Bioscience* ***3*(4)**: 132–141.

Ranganna S (1977) Manual of Analysis of Fruit and Vegetable products Tata McGraw-Hill publishing Company Limited, New Delhi. pp. 634.

Rashid MH (2013) Effects of different postharvest treatments and varieties on quality of banana. MS thesis, Department of Horticulture, BAU, Mymensingh.

Reyes MEQ, Nishijima W, Paull RE (1998) Control of crown rot in 'San Catarina Prata' and 'Williams' banana with hot water treatments. *Postharvest Biology and Technology* **14(1)**: 71–75. https://doi.org/10.1016/S0925-5214(98)00034-9

Sabir MS, Shah SZA, Afzal A (2004) Effect of chemical treatment, wax coating, oil dipping and different wrapping materials on Physio-chemical characteristics and storage behavior of apple (*Malus domestica* Borkh). *Pakistan Journal of Nutrition* **3(2)**: 122–127. doi:10.3923/pjn.2004. 122.127

Sadiq K, Irfan U, Nadeem K, Amjad I, Tariq S, Farooq S *et al.* (2016) The Role of LTST Hot Water Immersion on Quality of Peach Fruit during Storage. *Madridge Journal of Food Technology* **1(1)**: 31–36. doi:10.18689/mjft.2016–105

SajidM, Basit A, Ullah I, Tareen J, Asif M, Khan S *et al.* (2019) Efficiency of calcium chloride ($CaCl_2$) treatment on post-harvest performance of pear (*Pyrus communis* L.). *Pure and Applied Biology* **8(2)**: 1111–1125. http://dx.doi.org/10.19045/ bspab.2019.80053

Sarabandi K, Peighambardoust SH, Sadeghi Mahoonak AR *et al.* (2018) Effect of different carriers on microstructure and physical characteristics of spray dried apple juice concentrate. *Journal of Food Science and Technology* **55**: 3098–3109. https://doi.org/10.1007/s13197-018-3235-6

Sarabandi K, Peighambardoust SH, Mahoonak AS *et al.* (2017) Effect of carrier types and compositions on the production yield, microstructure and physical characteristics of spray dried sour cherry juice concentrate. *Food Measure* **11**: 1602–1612. https://doi.org/10.1007/s11694-017-9540-3

Sims AD and Gamon AJ (2002) Relationships between leaf pigment content and spectral reflectance across a wide range of species, leaf structures and developmental stages. *Remote Sensing of Environment* **81(2-3)**: 337–354. https://doi.org/10. 1016/S0034-4257(02)00010-X

Valverde JM, Valero D, Mart´ınez-Romero D, Guillen F,Castillo S, Serrano M (2005) "Novel edible coating based on *Aloe vera* gel to maintain table grape quality and safety," *Journal of Agricultural and Food* Chemistry **53(20)**: 7807–7813. doi: 10.1021/ jf050962v

Wang SY, Gao H (2013) Effect of chitosan-based edible coating on antioxidants, antioxidant enzyme system, and postharvest fruit quality of strawberries (*Fragaria x aranassa* Duch.), *LWT-Food Science and Technology* **52(2)**: 71–79. https://doi.org/10.1016 /j.lwt.2012.05.003

Waskar DP, Khedkar RM, Garande VK (1999) Effect of post-harvest treatments on shelf life and quality of pomegranate in evaporative cool chamber and ambient conditions. *Journal of Food Science and Technology* **36(2)**: 114–117.

Willats WGT, McCartney L, Mackie W, Knox JP (2001) Pectin: cell biology and prospects for functional analysis. *Plant Molecular Biology* **47(1-2)**: 9–27. doi:10.1023/A:1010662911148

Yaman O, BayoindirliL (2002) "Effects of an edible coating and ¨ cold storage on shelf-life and quality of cherries," *LWT - Food Science and Technology* **35(2)**: 146–150.https://doi.org/10.1006/fstl.2001. 0827