J Bangladesh Agril Univ 19(4): 437–446, 2021 https://doi.org/10.5455/JBAU.111596

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Original Article

Effects of Hot Water Treatments and Organic Extracts on Diseases, Shelf Life and Quality of Banana

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ARTICLE INFO

Article history
Received: 17 Aug 2021
Accepted: 20 Sep 2021
Published: 31 Dec 2021

Keywords
Banana,
Hot water,
Organic extract,
Diseases,
Shelf life,
Quality

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ABSTRACT

Banana is a climacteric fruit and highly perishable in nature and hence, consumption period is very short after harvesting. An experiment was conducted to study the effects of hot water treatments and organic extracts on diseases, shelf life and quality of banana. The experiment consisted of two hot water treatments viz. hot water at 50^{0}C for 5 min and hot water at 55^{0}C for 5 min, and five organic extracts viz. control, neem (*Azadirachta indica*) extract (1:1), aloe vera (*Aloe indica*) extract (1%), garlic (*Allium sativum*) extract (1:1) and chitosan coating @ 0.2%. The two-factor experiment was laid out in a completely randomized design with three replications. Hot water treatments and organic extracts had significant effects on all the parameters under study. Between the hot water treatments, 50^{0}C for 5 min treated fruits showed better physico-chemical characteristics than 55^{0}C for 5 min treated fruits at 12 days after storage (DAS). Other parameters such as weight loss, pulp to peel ratio, total soluble solids (TSS), pH, disease incidence and disease severity were found to increase during storage period. Disease incidence and severity were also significantly higher in all fruits during the entire period of experiment except garlic extracts treated fruits. The longest shelf life (15 days) was found with garlic extracts treated fruits. From the results, it may be concluded that hot water treatment at 50^{0}C for 5 min along with garlic extract (1:1) could be used to prolong the shelf life, reduce postharvest fungal infection and quality retention of banana.

Introduction

Banana (*Musa sapientum*) is one of the cheapest, most plentiful and nourishing of all fruits. It belongs to the family Musaceae. There are only two genus viz. *Ensete*, and *Musa* with about 50 species in this family. Banana is one of the tallest herbaceous plants with a pseudostem (Rahman et al., 2006). It is a tropical fruit of great acceptance and an economically important fruit available throughout the year. Among the fruit crops grown in Bangladesh, banana ranks first in terms of production comprising nearly 42% of the total. Bangladesh produces 833309 tons of bananas from 48870.04 hectare of land (BBS, 2019). It has nearly all the essential nutrients including minerals and vitamin. From the nutritional point of view, it contains carbohydrate, crude fiber, protein, fat, ash, phosphorous, iron, beta-carotene, riboflavin, niacin and ascorbic acid (Khader et al., 1996). It is also a rich source of energy (Islam et al., 2001). Banana is unique due to its high calories and nutritive values as compared to apple, it contains five times more vitamin A and iron, four times protein, three times phosphorus, twice the carbohydrate and the other vitamins and minerals (Zaman, et al., 2007). Nowadays, demand of banana consumption is increasing due to its high caloric and nutritional value, but non-availability of postharvest storage facilities has posed a great threat to the commercial cultivation of banana.

Postharvest loss of fresh fruits is one of the problems in the tropics. Most losses of fresh bananas occur between leaving the farm and reaching the consumer. Losses during this period have been estimated to be about 20% of the total crop (Golder et al., 2018). In Bangladesh, a considerable amount of banana is being spoiled due to prevailing high temperature and humidity during main harvesting period. There is a lack of appropriate storage facilities and the knowledge

Cite This Article

Das, B.B., Rashid, M.H.A., Hassan, M.K., 2021. Effects of Hot Water Treatments and Organic Extracts on Diseases, Shelf Life and Quality of Banana. *Journal of Bangladesh Agricultural University*, 19(4): 437–446. https://doi.org/10.5455/JBAU.111596

about storage is also insufficient. The enormity of postharvest losses of banana in Bangladesh ranges from 25-40% and it is only 5-25% in developed countries (Kader, 1992). Hassan (2010) reported that the postharvest loss of banana is 24.62% annually. Banana has a very short storage life. It is highly perishable, therefore susceptible to several diseases resulting in extensive postharvest losses (Basel et al., 2002). Among the postharvest diseases, anthracnose caused by *Colletotrichum musae*, is the most important disease causing and massive economic losses of bananas (Ranasinghe et al., 2003). Prolongation of shelf life of banana is required to reduce the postharvest losses. It has been reported that combined application of hot water plus aloe vera extract, followed by hot water plus garlic extract used to reduce fungal infection, extension of shelf life and quality retention of papaya fruits without affecting the nutritive value (Rashid et al., 2019). On the other hand, bananas are generally treated with the fungicides like prochloraz and imazalil to control postharvest pathogens (Aked et al., 2001). So, to avoid the early ripening and use of various fungicides, some alternatives and efficient methods could be applied for delay ripening and control the disease.

Plant extract viz. neem, garlic, onion, potato, mahogoni, allamanda, dutura, coating with sesame oil, cinnamon oil etc. are reported to have some fungicidal properties against certain postharvest diseases of tropical fruits which could delay ripening and increase the shelf life.

As a result, some scientists of Bangladesh using different promising plant extracts and other so many low prices extract as postharvest treatment to extend the shelf life of fruits (Islam et al., 2011). It is necessary to find out suitable methods to prolong shelf life of banana which will help to reduce postharvest loss. Therefore, the current experiment was undertaken to study the effects hot water treatments and organic extracts on diseases, shelf life and quality of banana.

Materials and Methods

Experimental location

The experiment was conducted at the Laboratory of the Department of Horticulture, Bangladesh Agricultural University, Mymensingh during the period from August to October 2019 to study the effects of hot water treatments and organic extracts on diseases, shelf life and quality of banana.

Experimental materials

Banana (var. Amritsagar) was selected as experimental material for the experiment. Freshly harvested bananas of uniform size, shape and color of commercial purposes were collected from Horticulture Farm of the Bangladesh Agricultural University (BAU), Mymensingh. Bananas were harvested in the morning hours and transferred to the Laboratory of the Department of Horticulture, BAU by van with careful handling to avoid injury. Following their arrival in the laboratory, bunches were cooled by providing cool air for 30 minutes to quickly remove the field heat. Individual fingers of uniform size were separated from the hands of bunches. The skins of banana were cleaned with the help of soft tissue paper just before setting.

Experimental treatments and design

Mature banana, physically similar of approximately more or less uniform in size, shape and colour were selected for this experiment. The experiment consisted of two hot water treatments viz. hot water at 50^0C for 5 min (H_1) and hot water at 55^0C for 5 min (H_2), and five organic extracts viz. control (T_0), neem extract (1:1) (T_1), aloe vera extract (1%) (T_2), garlic extract (1:1) (T_3) and chitosan coating (0.2%) (T_4). The two-factor experiment was laid out in a completely randomized design (CRD) with three replications. The postharvest treated fruits were assigned randomly in each replication. Three hundred uniform sized fruits were taken for the experiment. Ten banana fingers were used under each treatment from which 5 fruits were used as destructive sample and 5 were kept for colour changes, weight loss, disease incidence and severity and shelf life study. Therefore, total number of 300 fruits was used for this experiment for 10 treatment combinations for 3 replications.

Application of experimental treatments

The selected banana fruits were randomly assigned in the study for the postharvest treatments. After the application of treatments, the fruits were kept on a brown paper previously placed on the table in the laboratory at room temperature. Each treatment comprised of 10 fingers in each replication. The procedures of applying the postharvest treatments to the fruits were as follows.

Hot water treatments (50^0C & 55°C for 5 minutes)

For hot water treatment, thirty fingers of Amritsagar were selected and immersed into hot water bath for five minutes before placing them on the brown paper placed on the table in the laboratory at ambient atmospheric conditions (30±2°C and 66 to 74% RH).

Control

For control, fruits were randomly arranged with replication and kept on the brown paper placed on the table in the laboratory following same ambient atmospheric conditions.

Neem extract (1:1)

For neem treatment, leaves of neem were collected from BAU campus. Extract was prepared from the fresh green leaves with the help of an electric blender through maceration process. Neem extract was prepared by dissolving of neem leaf extract in one litre of distilled water and stirred gently by a glass rod in beaker and then the fruits were dipped into it for a period of 5 minutes of ensure that enough quantity of extract was being absorbed and were allowed to air dry for a period of 15 minutes and then kept on brown paper.

Aloe vera extracts (1%)

For aloe vera, aloe vera pulp was collected from 30 aloe vera leaves. Then the pulp was blended with a blender machine and filtered with a clean sterilized cloth. Thus the aloe vera gel was prepared. Then the selected fingers were dipped into the gel for 5 minutes and allowed to air dry for a period of 10 minutes and then kept on brown paper for observation at ambient condition.

Garlic extracts (1:1)

For garlic treatment, initially stock garlic extract (400 g garlic cloves and 400 ml water) was prepared by crushing the fresh doves in water using a blender and then cheesed. The stock extract was then used to prepare treatment concentrations of 1:1. The fruits were then dipped into the treatment solutions for 5 minutes to ensure that enough quantity of extract being absorbed. Those fruits were allowed to air dry for a period of 10 min and then kept on brown paper for observation.

Chitosan (0.2%)

Chitosan has been widely used as an edible coating for extending the shelf life of banana fruit. For chitosan coating, solution was prepared by dissolving chitosan in a solution of glacial acetic acid with stirring at 50°C. The resultant chitosan solution was filtered by vacuum filtration. Glycerol was added into chitosan in the solution and mixed for 30 min. Chitosan solution was prepared using 0.6% acetic acid, adding 25% glycerol (w/w chitosan) as plasticizer. Bananas were dipped into the prepared coating emulsions for 1 min and then drained. The treated and control banana samples were dried in ambient conditions (26±2°C and 40-50% RH) for 40 min. After setting a thin layer of edible coating on the surface of treated samples, control and coated banana samples were stored at ambient conditions in the laboratory.

Parameters studied

The parameters of banana studied in this experiment were external fruit colour change, total weight loss (%), pulp to peel ratio, total soluble solids (TSS) content of banana pulp (%Brix), pH of banana pulp, disease incidence (percentage of fruits infected), disease severity (percentage of fruits skin infected) and shelf life of banana. The parameters were measured in the following ways:

External colour

External fruit characters such as shape, size and thickness were recorded just after harvesting the fruits, changes in skin color were recorded during storage by matching the pericarp colours with a standard colour chart (RHS, 1995).

Total weight loss

Each replication of each treatment was weighed initially and held under different post-harvest treatments for data collection. Weight loss was calculated using the following formula:

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

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

Pulp to peel ratio

The fruits were peeled at the intervals of 3, 6, 9 and 12 days of storage. Pulp and peel both are separated from each other. Pulp to peel ratio was determined by separately weighing pulps and peels of fruits of each treatment and each replication by using electrical balance and then the pulp to peel ratio was calculated. The pulp was then used for other chemical analysis. The pulp to peel ratio was measured with the following formula:

$$\text{Pulp to peel ratio} = \frac{\text{Weight of fruit pulp}}{\text{Weight of peel}}$$

Total soluble solids (TSS) content of banana pulp (%Brix)

TSS content of banana fruit pulp was estimated using Abbe's refractometer. A drop of banana juice squeezed from the fruit pulp on the prism of the refractometer and percent TSS content were recorded as %Brix from direct reading of the instrument. Temperature corrections were made using the temperature correction chart that accompanied the instrument.

Pulp pH

The pH of fruit pulp was recorded by using an electric pH meter. The pH meter was standardised with the help of a buffer solution as described by Ranganna (1994).

Disease incidence

Disease incidence means percentage of banana infected with diseases. The incidence of banana was recorded at every 3 days intervals through visual observation of the disease symptoms already published. The disease incidence was calculated as follows:

$$\text{Disease Incidence (\%)} = \frac{\text{Number of banana infected}}{\text{Total number of banana}} \times 100$$

Disease severity

Disease severity represents the percentage diseased portion of infected fruit. All the infected fruits were taken to determine the percent fruit area infected and carefully evaluated. This evaluation was determined by eye estimation by calculating the mean values regarding the infected fruit areas. The assessment of this characteristic was done subjectively through scores related to the following scale adapted from Azevedo (1998): 1. Very bad – more than 50% of fruit with lesions, impossible to be made good use of; 2. Bad – lesions between 25 and 50% of fruit, not much exploitable; 3. Tolerable – lesions between 5 and 25% of fruit, not acceptable for trading, can be used as home consumption; 4. Good – lesions up to 5% of fruit, conditions acceptable for trading; 5. Excellent – without lesions, perfect phytosanitary quality.

Shelf life of banana

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

Statistical analysis

The collected data on various parameters were statistically analyzed using MSTAT statistical package program. 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 (Gomez and Gomez, 1984).

Results and Discussion

External colour

Hot water treatments had significant influence on external colour of banana fruits (Table 1). The fruit character showed a gradual increase in colour development in 50^0C and 55^0C hot water treatment under different plant extracts. The increasing rate of colour development is faster in control (T_0) followed by neem extract (T_1), chitosan (T_4), aloe vera extract (T_2). The slowest rate of colour development was found in garlic extract (T_3). Colour changes ratio is higher at hot water treatment at 55^0C for 5 min than hot water treatment at 50^0C for 5 min. Changes in the peel colour was observed at an interval of 3 days and found that colour changes was faster in fruits that exposed to prolonged duration of heat (Table 1 & Figure 1a-e). This might be due to the color of banana which is one of the most important criteria to the consumer for buying the fruits in the markets. The changes of peel color involve chlorophyll degradation or qualitative and quantitative alternations of the green pigments into other pigments.

Table 1. Changes in peel colour of banana fruit as influenced by different postharvest treatments at different days after storage

		Treatments				
Days of storage	Hot water temperature	Control (T_0)	Neem extract (T_1)	Aloe vera extract (T_2)	Garlic extract (T_3)	Chitosan (T_4)
0	50^0C	Full green	Full green	Full green	Full green	Full green
	55^0C	Full green	Full green	Full green	Full green	Full green
3	50^0C	Light yellow green	Yellow green, Dark green, Light yellow green	Yellow green, light yellow green	Dark green	Yellow green, light yellow green
	55^0C	Green yellow, Brown green	Yellow green	Yellow green	Dark green	Yellow green
6	50^0C	Yellow	Yellow. light yellow green	Yellow green, light yellow green, yellow	Dark green, light yellow	Yellow, light yellow, yellow green
	55^0C	Yellow	Yellow green, Yellow	Yellow, Light yellow	Dark green	Light yellow green, Yellow
9	50^0C	Light yellow, Yellow	Yellow	Yellow	Brown green, yellow, light yellow green	Yellow
	55^0C	Full yellow	Full yellow	Full yellow	Green, light yellow green	Full Yellow
12	50^0C	Black	Brown, light yellow brown	Light yellow brown, brown	Brown green, Yellow	Light yellow brown, Black
	55^0C	Brown, black	Light yellow, brown	Light yellow brown, light yellow	Yellow green	Orange yellow, Brown

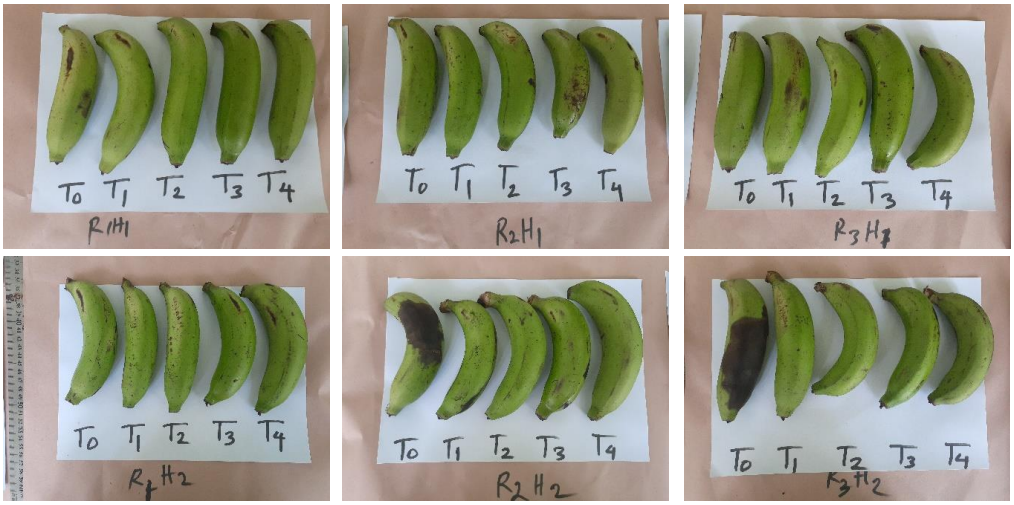

Figure 1a. Changes in peel colour of banana at 0 days after storage (DAS) as influenced by different postharvest treatments. R_1=Replication 1, R_2=Replication 2, R_3=Replication 3, H_1= Hot water at 50^{0}C for 5 min, H_2= Hot water at 55^{0}C for 5 min, T_0: Control, T_1: Neem extract (1:1), T_2: Aloe vera extract (1%), T_3: Garlic extract (1:1), T_4: Chitosan (0.2%).

Figure 1b. Changes in peel colour of banana at 3 days after storage (DAS) as influenced by different postharvest treatments. R_1=Replication 1, R_2=Replication 2, R_3=Replication 3, H_1= Hot water at 50^{0}C for 5 min, H_2= Hot water at 55^{0}C for 5 min, T_0: Control, T_1: Neem extract (1:1), T_2: Aloe vera extract (1%), T_3: Garlic extract (1:1), T_4: Chitosan (0.2%).

Figure 1c. Changes in peel colour of banana at 6 days after storage (DAS) as influenced by different postharvest treatments. R_1=Replication 1, R_2=Replication 2, R_3=Replication 3, H_1= Hot water at 50^{0}C for 5 min, H_2= Hot water at 55^{0}C for 5 min, T_0: Control, T_1: Neem extract (1:1), T_2: Aloe vera extract (1%), T_3: Garlic extract (1:1), T_4: Chitosan (0.2%).

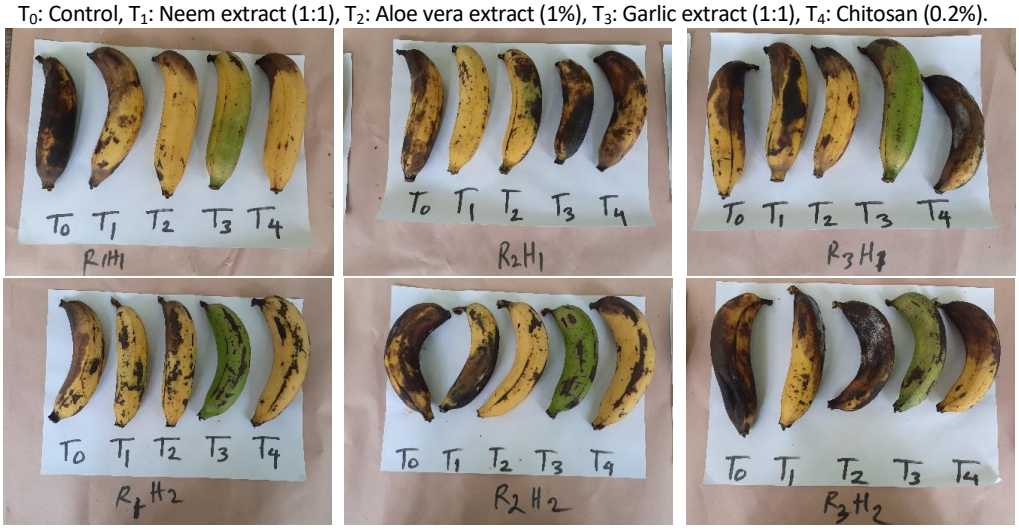

Figure 1d. Changes in peel colour of banana at 9 days after storage (DAS) as influenced by different postharvest treatments. R_1=Replication 1, R_2=Replication 2, R_3=Replication 3, H_1= Hot water at 50^{0}C for 5 min, H_2= Hot water at 55^{0}C for 5 min, T_0: Control, T_1: Neem extract (1:1), T_2: Aloe vera extract (1%), T_3: Garlic extract (1:1), T_4: Chitosan (0.2%).

Figure 1e. Changes in peel colour of banana at 12 days after storage (DAS) as influenced by different postharvest treatments. R_1=Replication 1, R_2=Replication 2, R_3=Replication 3, H_1= Hot water at 50^{0}C for 5 min, H_2= Hot water at 55^{0}C for 5 min, T_0: Control, T_1: Neem extract (1:1), T_2: Aloe vera extract (1%), T_3: Garlic extract (1:1), T_4: Chitosan (0.2%).

Weight loss

The combined effect of hot water treatments and organic extracts on total weight loss was found highly significant in all stages of observation during storage (Table 2). Hot water at 50^{0}C for 5 min under control treatment showed highest rate (23.90%) of weight loss and the lowest rate (20.12%) of weight loss was found under hot water at 55^{0}C for 5 min at 12th day of storage of banana (Table 2). The weight loss of bananas occurred due to the loss of water from the fruits, microbial decay and storage room environment like temperature and humidity (Hossain et al., 2017).

Pulp to peel ratio

The combined effects of hot water treatments and different organic extracts on pulp to peel ratio were statistically significant (Table 2). The highest pulp to peel ratio (4.80) was found in hot water at 50^{0}C with control treatment followed by hot water at 55^{0}C with control treatment (4.56), and both combinations were not possible to measure at 12 DAS (Table 3). Without control combination pulp to peel ratios were gradually increased up to 12th day of storage.

Total soluble solids (TSS) content

Combined effect of hot water treatments and organic extracts significantly influenced on TSS content (Table 3). The highest TSS (27.93 %) was observed in

neem extracts treated fruits of hot water at 50^{0}C for 5 min while the lowest TSS (25.27%) was observed from garlic treated fruits of hot water at 55^{0}C for 5 min (Table 3). The increasing of TSS 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 banana and other climacteric fruits and further hydrolysis decreased the TSS during storage. The increased ratio during storage may be related to the change in sugar concentration in the pulp compared to the peel. Thus, contributing to different change in osmotic pressure. Water is lost from the peel of banana both by transpiration and osmosis. As a result the peel weight is reduced and pulp to peel ratio increases. The increase in pulp to peel ratio during ripening was observed by Tripathi et al. (1981), Krishnamurthy (1993).

Table 2. Combined effects of hot water treatments and organic extracts on percent weight loss and pulp to peel ratio at different days after storage of banana

Treatment combination	Weight loss (%) at different days after storage				Pulp peel ratio at different days after storage			
	3	6	9	12	3	6	9	12
H_1T_0	6.57	10.58	19.64	23.90	3.38	4.41	4.10	4.80
H_1T_1	6.00	10.04	18.82	23.26	2.66	3.06	3.71	4.01
H_1T_2	5.74	9.58	18.42	21.96	2.60	3.51	3.94	3.88
H_1T_3	6.25	9.51	15.93	20.15	2.35	3.43	3.30	3.58
H_1T_4	6.43	10.16	18.32	23.38	3.05	4.07	3.48	3.46
H_2T_0	6.30	10.33	18.79	23.06	2.76	2.79	4.06	4.56
H_2T_1	5.83	9.58	18.18	23.15	1.93	2.71	3.57	3.73
H_2T_2	5.56	9.31	18.31	21.69	2.30	2.72	3.78	3.86
H_2T_3	6.21	8.54	14.97	20.12	2.21	2.21	3.09	3.33
H_2T_4	5.98	9.06	17.58	22.02	2.07	2.77	3.33	3.31
$LSD_{0.05}$	0.08	0.11	0.12	0.63	0.14	0.31	0.05	0.11
$LSD_{0.01}$	0.10	0.15	0.16	0.86	0.19	0.43	0.07	0.15
Level of significance	**	**	**	*	**	**	**	**

**, * = Significant at 1 and 5% levels of probability, respectively. H_1 = Hot water @ 50^{0}C for 5 min, H_2 = Hot water @ 55^{0}C for 5 min, T_0 = Control, T_1 = Neem extracts (1:1), T_2 = Aloe vera extracts (1%), T_3 = Garlic extract (1:1), T_4 = Chitosan (0.2%).

Table 3. Combined effects of hot water treatments and organic extracts on TSS content and pulp to peel ratio at different days after storage of banana

Treatment combination	TSS (% brix) at different days after storage				pH at different days after storage			
	3	6	9	12	3	6	9	12
H_1T_0	19.63	26.67	28.37	27.80	3.86	4.24	4.56	4.84
H_1T_1	16.13	28.33	28.70	27.93	4.30	4.25	5.05	5.12
H_1T_2	20.77	28.00	27.20	26.40	4.01	4.74	5.27	5.45
H_1T_3	15.27	19.93	28.20	25.83	4.46	4.92	5.20	5.76
H_1T_4	23.60	27.07	28.03	26.40	4.34	4.62	4.96	5.46
H_2T_0	15.77	26.47	27.77	27.46	3.67	4.14	4.55	4.83
H_2T_1	15.17	24.47	27.37	26.86	3.99	4.28	4.69	5.40
H_2T_2	18.03	27.87	27.07	26.72	4.28	4.69	4.90	5.28
H_2T_3	10.73	19.13	26.67	25.27	4.40	4.85	5.15	5.56
H_2T_4	22.40	27.00	27.97	27.28	4.12	4.61	4.99	5.32
$LSD_{0.05}$	0.74	0.46	0.52	0.12	0.08	0.054	0.054	0.09
$LSD_{0.01}$	1.00	0.63	0.72	0.16	0.10	0.073	0.073	0.13
Level of significance	**	**	**	**	**	**	**	**

** = Significant at 1% level of probability. H_1 = Hot water @50^{0}C for 5 min, H_2 = Hot water @55^{0}C for 5 min, T_0 = Control, T_1 = Neem extracts (1:1), T_2 = Aloe vera extracts (1%), T_3 = Garlic extract (1:1), T_4 = Chitosan (0.2%).

Pulp pH

The combined effect between the hot water treatments and various plant extracts exhibited significant variation in respect of pulp pH content (Table 3). The highest pulp pH (5.76) was observed in garlic extract treated fruits of hot water at 50^{0}C at 12

days of storage and the lowest pulp pH (4.83) was observed on hot water at 55^{0}C in untreated fruits of banana (Table 3). pH has effect on shelf life and microbial attack.

Disease incidence (%)

A significant variation was found on disease incidence in banana fruits during storage period due to the combined effect between the hot water treatments and various postharvest treatments of plant extracts (Table 4). Disease incidence data was recorded from 0 DAS up to 12 DAS, but initially (0 DAS) there was no infection by any disease. After that the disease incidence was found from 3 DAS and continued up to 12 DAS where 100% disease incidence were recorded at untreated fruits (control). In that case, control treatment did not produce longer shelf life of banana. The fruits treated with garlic extract gave the lower disease incidence recorded 46.67% in hot water at 50^{0}C and 53.33% in hot water at 55^{0}C at 12 DAS (Table 4 & Figure 1e).

Table 4. Combined effects of hot water treatments and organic extracts on percent disease incidence and severity at different days after storage of banana

Treatment combination	Disease incidence (%) at different days after storage				Disease severity (%) at different days after storage			
	3	6	9	12	3	6	9	12
H_1T_0	13.33	40.00	66.67	100.00	4.90	29.44	74.56	100.00
H_1T_1	0.00	13.33	40.00	66.67	0.00	26.56	75.56	91.44
H_1T_2	6.67	26.67	46.67	66.67	0.00	25.66	73.66	81.78
H_1T_3	0.00	6.67	27.67	46.67	0.00	22.56	45.44	55.33
H_1T_4	13.33	40.00	60.00	73.33	0.00	27.67	72.11	90.98
H_2T_0	20.00	53.33	80.00	100.00	6.22	31.56	77.44	100.00
H_2T_1	13.33	46.67	66.67	86.67	0.00	28.44	78.11	98.44
H_2T_2	6.67	26.67	46.67	66.67	0.00	26.56	75.55	93.33
H_2T_3	0.00	0.00	26.67	53.33	0.00	23.44	46.33	58.67
H_2T_4	6.67	26.67	53.33	80.00	0.00	27.56	73.33	98.11
$LSD_{0.05}$	0.82	9.33	9.58	9.83	0.34	0.88	0.90	1.48
$LSD_{0.01}$	1.11	12.73	13.06	13.41	0.46	1.20	1.23	2.01
Level of significance	**	**	**	*	**	**	**	**

**, * = Significant at 1 and 5% levels of probability, respectively. H_1 = Hot water @50^{0}C for 5 min, H_2 = Hot water @55^{0}C for 5 min, T_0 = Control, T_1 = Neem extracts (1:1), T_2 = Aloe vera extracts (1%), T_3 = Garlic extract (1:1), T_4 = Chitosan (0.2%).

Disease severity (%)

In combined effects of the hot water treatments and postharvest treatments with organic extracts showed highly significant variation in terms of percent disease severity during storage. Disease severity data was recorded from 0 DAS up to 12 DAS, but initially (0 DAS) there was no infection by any disease except the untreated fruits. After that the disease severity was found from 3 DAS and continued up to 12 DAS where 100% disease severity were recorded at untreated fruits (control). The fruits treated with garlic extract provided the lower disease severity recorded 55.33% in hot water at 50^{0}C and 58.67% in hot water at 55^{0}C at 12 DAS (Table 4 & Figure 1e). Plant extract treated fruits were protective to prevent the disease infection.

Shelf life of banana

The combined effect between the hot water treatments and different treatments with organic extracts were highly significant in case of shelf life of banana (Figure 2). The maximum shelf life (15.0 days) was found in (H_1) hot water at 50^{0}C with T_3 (garlic extracts) treated fruits combination (H_1T_3) followed by H_1T_2, H_1T_4, H_1T_1 and H_1T_0. The minimum shelf life (8.50 days) was recorded in (H_2) hot water at 55^{0}C with control treatment (H_2T_0) (Figure 2). The extension of shelf life of fruit has been one of the prime concerns of marketing throughout the record 73 of history (Desai et al., 1989; Hossain et al., 2017). Shelf life of any fruits calculates from the period of harvest up to rotting. The plant extracts treatments delayed the fruit softening by reducing the rate of starch and pectin degradation.

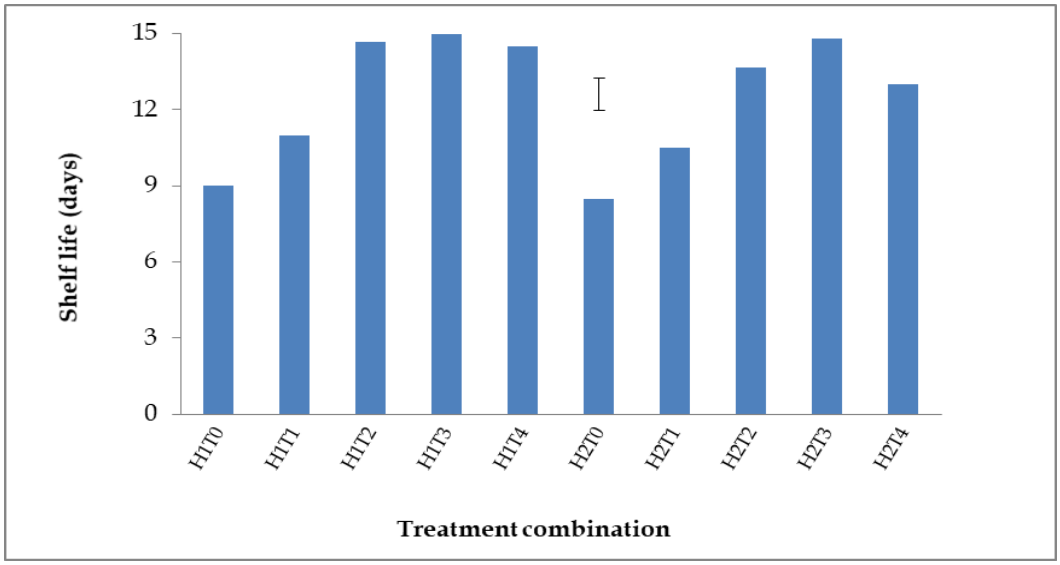

Figure 2. Main effect of the combination of hot water treatments and postharvest treatments of plant extracts on shelf life (days) at different days after storage. Vertical bar represents LSD at 1% level of probability. Here, H_1 = Hot water @ 50^0C for 5 min, H_2 = Hot water @ 55^0C for 5 min; T_0 = Control, T_1 = Neem extracts (1:1), T_2 =Aloe vera extracts (1%), T_3 = Garlic extract (1:1), T_4 = Chitosan (0.2%)

Conclusion

The experimental results revealed that the better physico-chemical properties, longest shelf life and fewer diseases were observed in hot water at 50^0C with garlic extract followed by the aloe vera extract treated fruits of banana. Garlic was more effective or promising plant extracts which showed better external appearance and colour, physico-chemical properties and significantly reduces the incidence and severity of fruits and extend the shelf of banana in this study. The shelf life of banana could be extended up to 15.00 days by treating with garlic extract. Therefore, it may be concluded that hot water treatment at 50^0C for 5 min along with garlic (1:1) extract could be used to prolong the shelf life, reduce the disease infection and retain the quality of banana.

Author Contribution

BBD performed the lab experiments, collected and analyzed the data and written the manuscript. MHAR Designed, formulated and supervised the experiment and reviewed the manuscript. MKH co-supervised the experiment and reviewed the manuscript.

Competing interests

The authors have declared that no competing interests exist

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