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Effects of Variety and Postharvest Treatments on Shelf Life and Quality of Banana

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Abstract: Banana is considered a short life commodity. Extended storage of bananas can be accomplished when ripening is not induced by a large ethylene exposure. Extension of shelf life banana would be possible by applying different promising postharvest treatments. The present study attempts to investigate the effect, of different postharvest treatments namely modified atmosphere with or without ethylene scavenging chemical ($KMnO_4$), cooling, low temperature and hot water treatment on shelf life and quality of 3 commercially important bananas namely Sabri, Champa and Amritasagar. The two-factor experiment was laid out in completely randomized design with three replications. Sabri, Champa and Amritasagar showed significant differences in time periods to reach successive stages of ripening. Longer period was required to reach ripening stages in variety Sabri than those of Champa and Amritasagar. Postharvest treatments and varieties were found to exhibit significant variation in total soluble solids (TSS) content during storage. The variety Sabri had the highest TSS content than that of Champa and Amritasagar. An increasing trend in TSS contents was observed in all varieties at all stages of ripening. The disease severity and disease incidence were greatly influenced by postharvest treatments and varieties during ripening and storage. All the treatments exhibited significant effects in relation to disease incidence. Modified atmosphere packaging with ethylene scavenger ($KMnO_4$) and storage of banana at 15°C resulted in reduced disease. Disease incidence was the lowest in Sabri variety than that of Champa and Amritasagar. Different postharvest treatments and varieties showed highly significant variation on shelf life. Results showed that the shelf lives of bananas of the variety Sabri, Amritasagar and Champa were 10.81, 9.00 and 10.11 days, respectively. Sabri had the longest shelf life (16.25 days) than two other varieties. Postharvest treatments exerted significant effects to extend shelf life of bananas. The longest shelf life of 15.58 days was observed in bananas held at 15°c temperature. Significant extensions of shelf life were also recorded in fruits held in plastic bags with or without $KMnO_4$. Combinedly, the longest shelf life was found in fruits of Sabri variety at 15°C. Considering the findings it may be concluded that significant variation existed due to the effects of different varieties and postharvest treatments in respect of prolongation of shelf life and other quality parameters of banana. The shelf life of banana could be extended up to 15.58 days in low storage temperature (15°C) and up to 10.91 days in modified atmosphere packaging with $KMnO_4$. The longer shelf lives of banana with the above mentioned treatments might be related to the slower changes in physico-chemical compositions.

Key wards: Banana, Different varieties, Postharvest treatments,

Introduction

Banana is a familiar fruit of Bangladesh. From its native southwestern Pacific home, the banana plant spreads to India by about 600 BC and later on it spreads all over the tropical world. It is possibly the world's oldest cultivated crop. Banana (*Musa sapientum*, family Musaceae) is one of the tallest of the herbaceous plants with a pseudostem (Rahman *et al.*, 2006). Banana occupies an important position among the fruits of Bangladesh not only for its highest production among the fruits but also for its increasing popularity to many farmers as an economic crop. Among the fruit crops grown in Bangladesh, banana ranks first in terms of production comprising nearly 42% of the total. Bangladesh produces 818254 metric tons of bananas from 53948.54 ha of land (BBS, 2010). Varieties of banana grown in Bangladesh are Amritasagar, Mehersager, Sabri, Champa, Chini Champa, Kabuli, Jahaji, Agnishwar, Basrai, Seeded banana, Anaji or Kancha Kola and Singapuri, etc. (Haque, 1988).

There is a great demand of banana among the people of Bangladesh. It is equally liked by all age groups of people in the country because it is easily digestible and palatable. From the nutritional point of view, it has high caloric and nutritional values. It contains carbohydrate, crude fiber, protein, fat, ash, phosphorous, iron, β-carotene, riboflavin, niacin and ascorbic acid (Khader *et al.*, 1996). Nowadays, demand of banana consumption is increasing day by day due to its high caloric and nutritional value, but non-availability of adequate postharvest storage facilities has posed a great threat to the commercial cultivation of banana. Appropriate storage facilities and knowledge about storage are insufficient. As a result, considerable amount of banana is spoiled every year. Banana is a perishable fruit and its postharvest loses range from 25-50% (Amiruzzaman, 1990). This loss occurs during transporting and marketing due to

adverse physiological changes (loss of weight due to increased respiration and transpiration), softening of flesh and lack of resistance capacity against microbial attack. In Bangladesh postharvest losses of banana due to environmental drivers (high temperature and humidity) ranges from 25-40% and it is only 5-25% in developed countries (Kader, 1992). Recently Hassan (2010) reported that the postharvest loss of banana is 24.62% which accounts for 56.7 crore taka annually.

Bananas are highly perishable fruits. Extended storage of bananas can be obtained when ripening is not induced by a large ethylene exposure (exogenous or endogenous). Shelf life can be extended by different processes such as modified atmosphere packaging (MAP) (Basel *et al.,* 2002; Hassan, 2000). Prolongation of shelf life may be achieved by several methods. Scott *et al*. (1971) mentioned that the ripening of banana is delayed when stored in sealed polythene cover and the minimal fruit losses were recorded in sealed polythene along with $KMnO_4$ (Bhadra and Sen, 1997). Proper harvesting is also important. Bananas should be harvested at appropriate stage of maturity for transport, handling and storage. It is necessary to delay ripening for distant markets and then enhance ripening for retail sale (Rao, 1979). Postharvest loss of banana is also occurred due to inappropriate postharvest handling and very poor knowledge in the field of postharvest technology as well as postharvest pathology. The postharvest losses of banana can be reduced considerably by applying improved technologies. The use of synthetic chemicals for the reduction of postharvest losses and extrusion of shelf life of perishables is a threat to human health and environment. Recently, a number of chemicals have been withdrawn from the market upon report of health hazards. Efforts should be made to optimize or develop suitable alternatives such as modified atmosphere packaging with or without ethylene scavenging compounds, hot water treatments, cooling, etc. for postharvest reduction loss of banana extension of shelf life with retained quality.

Therefore, improvement of shelf life of banana is an urgent need to reduce the postharvest losses and contribute to the uplift of the national economy. Hence, it is necessary to reduce enormous postharvest spoilage. Efforts to find out suitable method of storage and shelf life extension are important for reducing postharvest losses. Therefore, systematic studies on the postharvest behavior of commercial banana varieties of Bangladesh are important. Keeping these points in view, the present experiment was undertaken with the following specific objectives:

a) To investigate the effects of variety on shelf life and quality of banana,
b) To assess the shelf life of banana under different storage conditions,
c) To study the physico-chemical changes during storage and ripening, and
d) To find out the suitable storage methods to prolong shelf life of banana without deteriorating fruit quality.

Materials and Methods

Experimental location

The detailed methodologies followed to carry out the present experiment are given in the following. The experiment was conducted at the laboratory of Department of Horticulture, Bangladesh Agricultural University, Mymensingh. The maximum and minimum temperatures as well as relative humidity's in the storage room were 30° and 25.8°C and 86 and 66% respectively. Temperature and relative humidity of the storage room were recorded with a digital Temperature-humidity recorder (Thermo, Germany).

Experimental materials

Freshly harvested bananas of uniform size, shape and color of commercial varieties namely Sabri, Champa and Amritasagar were collected from farmer's garden of Telki Village in Madhupur of Tangail district. Three varieties of banana were harvested in the morning hours and transferred to the BAU campus as early as possible firstly by Van and then after by two stroke three wheeler with careful handling to avoid injury and placed in shelf life room Postgraduate Laboratory, Department of Horticulture, Bangladesh Agricultural University (Plate 1). Following their arrival in the laboratory bunches were cooled by air condition to quickly remove the field heat. Both upper and lower 1-2 hands of each cultivar were cut off for ensuring the experimental unit of more or less uniform. Individual fingers were separated from the hands of bunches and one hundred ninety two fingers of each varieties were used for the experiment. Brief descriptions of the banana varieties are shown in the following.

Experimental design

The two-factor experiment was laid out in completely randomized design (CRD) with three replications of eight fruits per replication.

Methods

Mature green bananas of more or less uniform size, shape and color were selected. A total of one hundred ninety two tots of each variety were selected for conducting the experiment. The skins of banana were cleaned with the help of soft tissue paper just before

setting. The bananas were harvested for the same plantation to avoid variation in experimental fruits.

Experimental treatments

The experiment consists of two factors as follows:

Factor A: Variety

V1- Sabri
V2- Champa
V3- Amritasagar

Factor B: Postharvest treatments

T1: Control
T2: Cooling for field heat removal at 5°C for 30 minutes
T3: Cooling for field heat removal at 10°C for 30 minutes
T4: Low temperature storage at 15°C
T5: Hot water treatment at 50± 2 °C for 5 minutes
T6: Modified atmospheric packaging without perforations
T7: Modified atmospheric packaging with perforations
T8: Modified atmospheric packaging with ethylene scavenger, KMnO4

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 laboratory floor at room temperature. Each treatment comprised of three replications of eight fingers. The procedures of applying the postharvest treatments to the fruits of each variety were as follows.

Control

Twenty four fingers of each variety were randomly selected and kept on the brown paper placed on the laboratory table at ambient conditions for observation.(25.8-30°C and 63-86% Rh).

Cooling at 5℃ for field heat removal

Twenty four fingers of each variety were randomly selected and held in refrigerated incubator (FOC 255 I, Velp Scientifica) at 5°C for 30 minutes. After then the bananas were brought out and kept on the brown paper placed on the table of the laboratory at ambient conditions for observation.

Cooling at 10℃ for field heat removal

Twenty four fingers of each variety were randomly selected and held in refrigerated incubator (FOC 255 I, Velp Scientifica) at 10°C for 30 minutes. After then the bananas were brought out and kept on the brown paper placed on the table of the laboratory at ambient conditions for observation.

Modified atmospheric packaging with ethylene scavenger, $KMnO_4$

Firstly, cotton were soaked with saturated $KMnO_4$ solution and sealed in smaller transparent perforated polythene (8cm×5cm). Then each banana fingers were individually sealed (using impulse plastic heat sealer, TISH 300) in a transparent polythene bag (20cm×20cm) along with smaller packet containing $KMnO_4$ soaked cotton. Care was taken so that bananas did not touch the $KMnO_4$ soaked cotton.

Storage at 15℃

For low temperature storage, twenty four fingers of each variety were selected and randomly arranged with replication and kept in the refrigerated incubator (FOC 255 I, Velp Scientifica) where temperature were maintained at 15°C.

Hot water treatment

For hot water treatment, the banana fingers were immersed into hot water (50±2°C) for five minutes before placing them on the brown paper placed on the table in the laboratory at ambient atmospheric conditions. For hot water treatment, a hot water bath was used.

Modified atmospheric packaging with perforations

Individual banana fingers were kept sealed in transparent perforated polythene by electric sealer and kept on the brown paper placed on the table in the laboratory at ambient atmospheric conditions for observations. Eight perforation of 5 mm diameter were made on each polythene bag.

Modified atmospheric packaging without perforations

Individual banana fingers were sealed in transparent unperforated polythene and held on the brown paper placed on the table in the laboratory at ambient atmospheric conditions for observations.

Data collection

Changes in the different parameters namely total soluble solids, disease incidence, disease severity, causal pathogens and shelf life were investigated. The methods of studying above-mentioned parameters are discussed in the following.

Parameters studied

In the present experiment the following parameters were studied:

- **Chemical characters:** total soluble solids.
- **Microbial characters:** disease incidence, disease severity and causal pathogens.

The experimental fruits were cleaned by tissue paper to remove the dirt and latex before applying the treatments. Among 8 fruits in each replication of each treatment, 4 fruits were used for destructive sampling at 3 days interval to investigate several parameters including moisture content, dry matter content and TSS. The remaining 4 fruits were used to investigate colors, firmness, total weight loss, disease incidence, disease severity and shelf life. The methods of studying the above parameters are described below:

Total soluble solids

Total soluble solids (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 Total soluble solids content were recorded as %Brix from direct reading of the instrument. Temperature corrections were made using the temperature correction chart that accompanied the instrument.

Disease incidence

Disease incidence means percentage of banana infected with diseases. The incidence of banana was recorded at every 3 days intervals. The diseased fruits were identified symptomatically. The disease incidence was calculated as follows:

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

Disease severity

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

Isolation and identification of causal pathogens

Representative samples of diseased fruits were collected and taken to the laboratory of the department of plant pathology, Bangladesh Agricultural University, Mymensingh for isolation and identification of causal organisms. Diseased samples with typical symptoms were selected and 10 semi-permanent slides were prepared. Then the prepared slides were observed under compound microscope for identifying the pathogenic structures. After 24 hours the prepared slides were made permanent by using nail polish and taken in the central laboratory, BAU, to take photographic image of the organisms.

Shelf life

Shelf life of banana fruits as influenced by different postharvest treatment 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 MSTST C 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, 1984).

Results and Discussion

The results of the present study on changes in various physico-chemical parameters during storage and ripening of three varieties of banana are presented and discussed in this chapter. Postharvest storage behavior namely total soluble solids, disease incidence, disease severity, causal pathogens and shelf life of bananas as observed during the study have been presented and discussed.

Disease incidence

There were significant disease incidence found in all the three varieties during ripening and storage. At the 9^{th} day Amritasagar showed highest (78.06%) incidence but Sabri showed lowest (70.83%) disease incidence (Table 1).

Table 1. Main effects of varieties on diseases incidence of banana during storage and ripening.

Variety	**Disease incidence at different days of storage**				
	3	**6**	**9**	**12**	**15**
Sabri	39.58	52.08	70.83	58.332	50
Champa	15.62	44.74	72.91	54.167	58.33
Amritasagar	59.37	64.58	78.06	54.165	58.33
$LSD_{(0.05)}$	0.55	0.81	1.39	0.91	0.634
$LSD_{(0.01)}$	0.74	1.09	1.89	1.23	0.87
Level of significance	**	**	**	**	**
CV%	2.40	2.52	3.15	2.74	3.86

** = Significant at 1% level of probability.

All the treatments exhibited significance differences in influencing disease incidence (Table 2). Modified atmosphere packaging and Storage at 15°C showed lower disease incidence.

Table 2. Main effects of treatments on disease incidence of banana during storage and ripening

Variety	**Disease incidence at different days of storage**				
	3	**6**	**9**	**12**	**15**
T_1	44.44	66.66	86.11	-	-
T_2	50	77.77	88.89	-	-
T_3	47.22	74.88	88.89	-	-
T4	19.44	19.44	33.33	47.22	55.55
T5	49.99	61.11	80.55	-	-
T6	25	30.55	55.55	-	-
T_7	33.33	66.66	94.44	-	-
T8	36.11	33.33	63.74	63.88	-
$LSD_{(0.05)}$	0.97	1.45	2.48	ND	ND
$LSD_{(0.01)}$	1.40	2.08	3.57	ND	ND
Level of significance	**	**	**	-	-
CV%	2.40	2.52	3.15	-	-

** = Significant at 1% level of probability, ND=Statistical analysis was not done. T1 = Control, T2 = Cooling at 5°C for 30 minutes, T3 =Cooling at 10°C for 30 minutes, T4 = Storage at 15°C, T5 = Hot water treatment at 50±2°C for 5 minutes, T6 = Modified atmosphere packaging without perforation, T7 = Modified atmosphere packaging with perforation and T8 =Modified atmosphere packaging with $KMnO_4$.

The combined effects of variety and treatments in influencing disease incidence of banana during ripening and storage were significant (Table 3). At 9th day of storage in Amritasagar treatment with control condition, cooling at 5°C, hot water treatment and modified atmosphere packaging with perforation and in Champa treatment with cooling at 10°C showed 100% disease incidence (Table 5).

Table 3. Combined effects of variety and postharvest treatments on disease incidence of banana during storage and ripening.

Variety	**Treatments**	**Disease incidence at different days of storage**				
		3	**6**	**9**	**12**	**15**
Sabri	**T_1**	50.00	75.00	83.33	-	-
	T_2	66.67	66.67	75.00	-	-
	T_3	41.67	58.33	75.00	-	-
	T4	16.67	16.67	25.00	33.33	50.00
	T5	50.00	58.33	75.00	-	-
	T6	33.33	33.33	75.00	-	-
	T_7	33.33	66.67	91.67	-	-
	T8	25	41.67	66.67	83.33	-
Champa	**T_1**	30.00	33.33	75.00	-	-
	T_2	16.67	83.33	91.67	-	-
	T_3	16.67	66.33	100	-	-
	T4	25.00	25.00	41.67	50.00	58.33
	T5	8.33	33.33	66.67	-	-
	T6	16.67	25.00	58.33	-	-
	T_7	8.33	58.33	91.67	-	-
	T8	33.33	33.33	58.33	58.33	-
Amritasagar	**T_1**	83.33	91.67	100	-	-
	T_2	66.67	83.32	100	-	-
	T_3	83.33	100	91.67	-	-
	T4	16.67	16.67	33.33	58.33	58.33
	T5	91.66	91.67	100	-	-
	T6	25.00	33.33	33.33	-	-

	T_7	58.33	75.00	100	-	-
	T8	50.00	25.00	66.22	50	-
$LSD_{(0.05)}$		1.50	2.23	3.83	ND	ND
$LSD_{(0.01)}$		2.00	2.97	5.10	ND	ND
Level of significance		**	**	**	-	-
CV%		2.40	2.52	3.15	-	-

** = Significant at 1% level of probability, ND=Statistical analysis was not done. T1 = Control, T2 = Cooling at 5°C for 30 minutes, T3 =Cooling at 10°C for 30 minutes, T4 = Storage at 15°C, T5 = Hot water treatment at 50±2°C for 5 minutes, T6 = Modified atmosphere packaging without perforation, T7 = Modified atmosphere packaging with perforation and T8 =Modified atmosphere packaging with $KMnO_4$.

Disease severity

The banana surface disease was greatly influenced by postharvest treatments in case of all varieties. Postharvest treatments exerted significant result in terms disease severity. The maximum (25.52 %) disease severity was observed in Amritasagar at the 9th day of storage (Table 4). All the varieties caused significant effect on the levels of disease severity but Sabri showed less disease severity as compared to other varieties.

Table 4. Main effects of varieties on disease severity of banana during storage and ripening.

Variety	**Disease severity at different days of storage**				
	3	**6**	**9**	**12**	**15**
Sabri	1.06	1.94	9.16	6.665	3.75
Champa	1.78	4.22	25.52	9.17	6.25
Amritasagar	1.42	2.59	17.72	6.335	3.75
$LSD_{(0.05)}$	0.05	0.06	0.32	0.13	0.08
$LSD_{(0.01)}$	0.08	0.092	0.44	0.18	0.11
Level of significance	**	**	**	**	**
CV%	6.22	3.95	3.04	2.97	5.70

** = Significant at 1% level of probability.

Remarkable variation in disease severity was observed between the different treatments. The lowest disease level (0.38) was found in bananas which was stored at 15°C and highest disease level (26.97) was found in fruit cooled at 5°C at the 9th days of storage. At the 12th day of storage all the treated fruits were completely damaged except modified atmosphere packaging with KMnO4 and held at 15°C (Table 5).

Table 5. Main effects of postharvest treatments on disease severity of banana during storage and ripening.

Variety	**Disease severity at different days of storage**				
	3	**6**	**9**	**12**	**15**
T_1	2	6.27	17.75	-	-
T_2	1.41	3.91	26.97	-	-
T_3	1.19	4.05	31.91	-	-
T4	0.38	0.47	1.77	3.39	4.583
T5	3.75	2.55	19.54	-	-
T6	0.53	1.08	7.75	-	-
T_7	1.14	4.27	26.08	-	-
T8	0.97	0.75	7.97	11.39	-
$LSD_{(0.05)}$	0.09	0.12	0.57	ND	ND
$LSD_{(0.01)}$	0.14	0.17	0.82	ND	ND
Level of significance	**	**	**	-	-
CV%	6.22	3.95	3.04	-	-

** = Significant at 1% level of probability, ND=Statistical analysis was not done. T1 = Control, T2 = Cooling at 5°C for 30 minutes, T3 =Cooling at 10°C for 30 minutes, T4 = Storage at 15°C, T5 = Hot water treatment at 50±2°C for 5 minutes, T6 = Modified atmosphere packaging without perforation, T7 = Modified atmosphere packaging with perforation and T8 =Modified atmosphere packaging with $KMnO_4$.

The combined and interaction effects of verities and postharvest treatments on disease severity levels were highly significant .The maximum disease severity level (44.58%) was observed in the treatment of cooling at 10°C in the variety Amritasagar. However, least disease severity was observed in fruits of all varieties at 15°C (Table 6).

Table 6. Combined effects of variety and postharvest treatments on disease severity of banana during storage and ripening

Variety	**Treatments**	**Disease severity at different days of storage**				
		3	**6**	**9**	**12**	**15**
Sabri	**T_1**	1.75	3.83	4.5	-	-
	T_2	1.58	1.83	10.5	-	-
	T_3	1.08	2.42	16.58	-	-
	T4	0.33	0.33	1.25	2.08	3.75
	T5	1	1.92	13.67	-	-
	T6	0.67	1.17	8.75	-	-
	T_7	1.58	3	11.67	-	-
	T8	0.5	1.08	6.42	11.25	-
Champa	**T_1**	0	5.17	13.33	-	-
	T_2	0.33	3.65	35.83	-	-
	T_3	0.33	3	34.58	-	-
	T4	0.5	0.75	2	2.67	3.75
	T5	8.33	2.42	7.79	-	-
	T6	0.17	1	7.08	-	-
	T_7	0.42	4.08	32	-	-
	T8	1.33	0.67	9.17	10	-
Amritasagar	**T_1**	4.25	9.83	35.42	-	-
	T_2	2.33	6.25	34.58	-	-
	T_3	2.17	6.75	44.58	-	-
	T4	0.33	0.33	2.08	5.42	6.25
	T5	1.92	3.33	37.17	-	-
	T6	0.75	1.07	7.42	-	-
	T_7	1.42	5.75	34.58	-	-
	T8	1.08	0.5	8.33	12.92	-
$LSD_{(0.05)}$		**0.15**	**0.19**	**0.87**	ND	ND
$LSD_{(0.01)}$		**0.19**	**0.25**	**1.17**	ND	ND
Level of significance	**	**	**	**	**	-	-
CV%		**6.22**	**3.95**	**3.04**	-	-

** = Significant at 1% level of probability, ND=Statistical analysis was not done. T1 = Control, T2 = Cooling at 5°C for 30 minutes, T3 =Cooling at 10°C for 30 minutes, T4 = Storage at 15°C, T5 = Hot water treatment at 50±2°C for 5 minutes, T6 = Modified atmosphere packaging without perforation, T7 = Modified atmosphere packaging with perforation and T8 =Modified atmosphere packaging with $KMnO_4$.

Total soluble solids

Total soluble solids contents of fruit pulp of different varieties were found to be statistically significant. Percent total soluble solids contents increased with storage period (Table 7). The highest Total soluble solids contents (26.29%) was found in Sabri at 9th day of storage and the lowest total soluble solids content (12.22%) was found in Amritasagar at 3th day of storage.

Table 7. Main effects of varieties on TSS of banana during storage and ripening

Variety	TSS at different days of storage		
	3	**6**	**9**
Sabri	15.44	25.2	26.29
Champa	18.89	21.2	24.81
Amritasagar	12.22	24.33	24.56
$LSD_{(0.05)}$	0.413	0.547	0.515
$LSD_{(0.01)}$	0.559	0.742	0.698
Level of significance	**	**	**
CV%	4.46	3.89	3.43

** = Significant at 1% level of probability.

The different storage treatments used in the investigation showed statistically significant variations in relation to percent TSS at all ripening stages. The maximum value of TSS (27.11% Brix.) was observed at the 6th day of storage in controlled condition (Table 8).

Table 8. Main effects of postharvest treatments on TSS of banana during storage and ripening

Variety	TSS at different days of storage		
	3	**6**	**9**
T_1	15.00	27.11	25.66
T2	14.61	25.88	26.33
T3	15.5	26.05	26.77
T4	13.44	17.55	23.11
T5	17	22	25.61
T6	16.88	22.66	23.83
T7	16.77	22.27	24.33
T8	14.96	25.11	26.11
$LSD_{(0.05)}$	0.74	0.98	0.92
$LSD_{(0.01)}$	1.06	1.40	1.32
Level of significance	**	**	**
CV%	4.46	3.89	3.43

** = Significant at 1% level of probability, ND=Statistical analysis was not done. T1 = Control, T2 = Cooling at 5°C for 30 minutes, T3 =Cooling at 10°C for 30 minutes, T4 = Storage at 15°C, T5 = Hot water treatment at 50±2°C for 5 minutes, T6 = Modified atmosphere packaging without perforation, T7 = Modified atmosphere packaging with perforation and T8 =Modified atmosphere packaging with $KMnO_4$.

The combined effects of variety and postharvest treatments were significant during the entire period of storage. Increase of TSS content was observed in the present investigation agrees with the report by Abdullah *et al.* (1985) and Sarker *et al,* (1995). The degree of increase in TSS value for different postharvest treatments might be due to the modified internal atmosphere and physiological aspects of banana fruits, suppressed respiration and metabolic processes, which involve in increasing TSS at different magnitudes.

Table 8. Combined effects of variety and postharvest treatments on TSS of banana during storage and ripening

Variety	Treatments	TSS at different days of storage		
		3	**6**	**9**
Sabri	T1	15.00	23.33	29.16
	T2	15.00	23.00	26.33
	T3	15.16	24.66	26.33
	T4	16.83	22.00	23.33
	T5	15.16	25.33	26.33

	T6	18.16	28.00	25.5
	T7	15.16	27.33	27.00
	T8	13.06	28.00	26.33
Champa	T1	16.00	30.33	25.5
	T2	19.00	28.66	27.33
	T3	19.66	29.00	27.00
	T4	12.5	14.66	25.00
	T5	21.66	15.66	24.00
	T6	20.66	14.33	21.00
	T7	22.00	14.00	23.00
	T8	19.66	23.00	25.66
Amritasagar	T1	14.00	27.66	22.33
	T2	9.83	26.00	25.33
	T3	11.66	24.5	27.00
	T4	11.00	16.00	21.00
	T5	14.16	25.00	26.5
	T6	11.83	25.66	25.00
	T7	13.16	25.5	23.00
	T8	12.16	24.33	26.33
$LSD_{(0.05)}$		1.14	1.50	1.41
$LSD_{(0.01)}$		1.51	2.02	1.89
Level of significance		**	**	**
CV%		4.46	3.89	3.43

** = Significant at 1% level of probability, ND=Statistical analysis was not done. T1 = Control, T2 = Cooling at 5°C for 30 minutes, T3 =Cooling at 10°C for 30 minutes, T4 = Storage at 15°C, T5 = Hot water treatment at 50±2°C for 5 minutes, T6 = Modified atmosphere packaging without perforation, T7 = Modified atmosphere packaging with perforation and T8 =Modified atmosphere packaging with $KMnO_4$.

Shelf life of banana

Shelf life is the period from harvesting up to the last edible stage. Significant variation was obtained among the varieties in relation to shelf life extension of bananas . Sabri bananas had the longest shelf life (10.81 days) followed by Champa (10.11 days) and Amritasagar (9.00 days) (Figure 1). Similar results were also obtained by the effects of different postharvest treatments used in the investigation were significant in respect of prolonging the shelf life of banana .

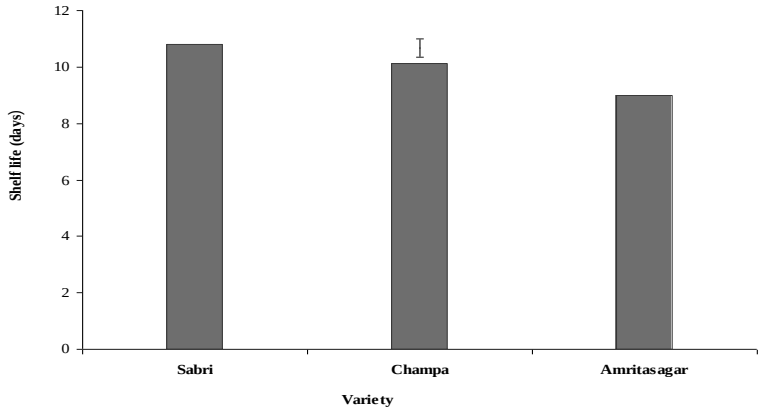

Fig.1. Main effects of varieties on shelf life of banana during storage and ripening. Vertical bar represents LSD at 1 % level of significance. T1 = Control, T2 = Cooling at 5°C for 30 minutes, T3 =Cooling at 10°C for 30 minutes, T4 = Storage at 15°C, T5 = Hot water treatment at 50±2°C for 5 minutes, T6 = Modified atmosphere packaging without perforation, T7 = Modified atmosphere packaging with perforation and T8 =Modified atmosphere packaging with $KMnO_4$.

The longest shelf life (15.58 days) was observed in bananas stored at low temperature storage at 15°C, whereas the shortest shelf life (8.08 days) was recorded in control fruits. Modified atmosphere packaging with ethylene scavenging compound ($KMnO_4$) also showed prolonged shelf life as compared to control treatment (Fig. 2). Another striking result of the study was that the significant extension of shelf life was also obtained in bananas held under modified atmosphere condition with or without perforations, especially when stored with $KMnO_4$ (Table 9).

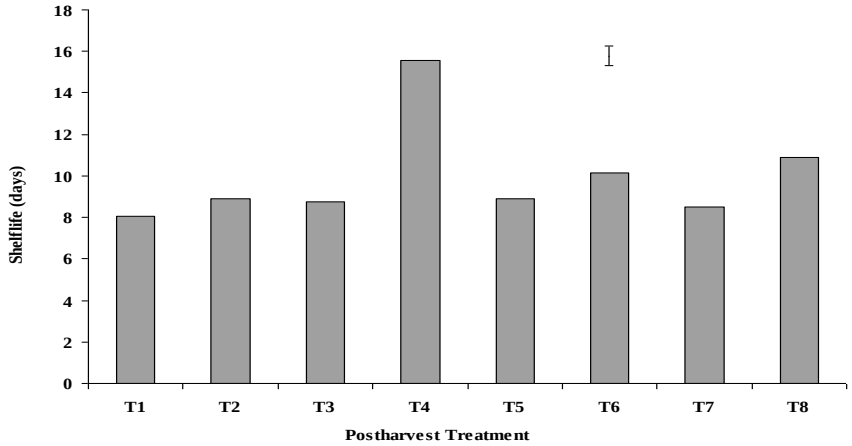

Fig.2. Combined effects of variety and postharvest treatments on shelf life of banana. Vertical bars represent LSD at 1 % level of significance. T1 = Control, T2 = Cooling at 5°C for 30 minutes, T3 =Cooling at 10°C for 30 minutes, T4 = Storage at 15°C, T5 = Hot water treatment at 50±2°C for 5 minutes, T6 = Modified atmosphere packaging without perforation, T7 = Modified atmosphere packaging with perforation and T8 =Modified atmosphere packaging with $KMnO_4$.

The combined and interaction effects of different varieties and postharvest treatments were significant on shelf life extension of banana. The longest shelf life (16.25 days) was observed in Sabri bananas when held at 15°C temperatures (Table 9). By contrast, the shortest shelf life (7.25 days) was recorded in bananas of variety Amritasagar when not subjected to any treatment (Table 9).

Table 9. Combined effects of variety and postharvest treatments on shelf life of banana.

Variety	Treatments	**Shelf life at different days of storage**
Sabri	T1 = Control	9.25
	T2 = Cooling at 5°C for 30 minutes	10.25
	T3 =Cooling at 10°C for 30 minutes	10.25
	T4 = Storage at 15°C	16.25
	T5 = Hot water treatment at 50±2°C for 5 minutes	9.5
	T6 = Modified atmosphere packaging without perforation	10
	T7 = Modified atmosphere packaging with perforation	9.75
	T8 =Modified atmosphere packaging with $KMnO_4$	11.25
Champa	T1 = Control	8.25
	T2 = Cooling at 5°C for 30 minutes	9
	T3 =Cooling at 10°C for 30 minutes	8.75
	T4 = Storage at 15°C	16
	T5 = Hot water treatment at 50±2°C for 5 minutes	9.75
	T6 = Modified atmosphere packaging without perforation	10.17
	T7 = Modified atmosphere packaging with perforation	8.5
	T8 =Modified atmosphere packaging with $KMnO_4$	10.5
Amritasagar	T1 = Control	6.75

	T2 = Cooling at 5°C for 30 minutes	7.5
	T3 =Cooling at 10°C for 30 minutes	7.25
	T4 = Storage at 15°C	14.5
	T5 = Hot water treatment at 50±2°C for 5 minutes	7.5
	T6 = Modified atmosphere packaging without perforation	10.29
	T7 = Modified atmosphere packaging with perforation	7.25
	T8 =Modified atmosphere packaging with $KMnO_4$	11
$LSD_{(0.05)}$		0.67
$LSD_{(0.01)}$		0.90
Level of significance		**
CV%		4.12

** = Significant at 1% level of probability, NS = Non-significant

These extended shelf life due to low temperature and modified atmosphere packaging were possibley due to the inhibition of ripening rates as contributed by the reduced physiological process, decay and weight loss.

Identification of diseases and pathogens from infected fruits

One fungal pathogen, namely *Colletotrichum musae* was indicates from the infected bananas. The bananas were predominantly infected by Anthracnose diseases as characterized by the formation of black spots on the fruit surface (Plate 1).

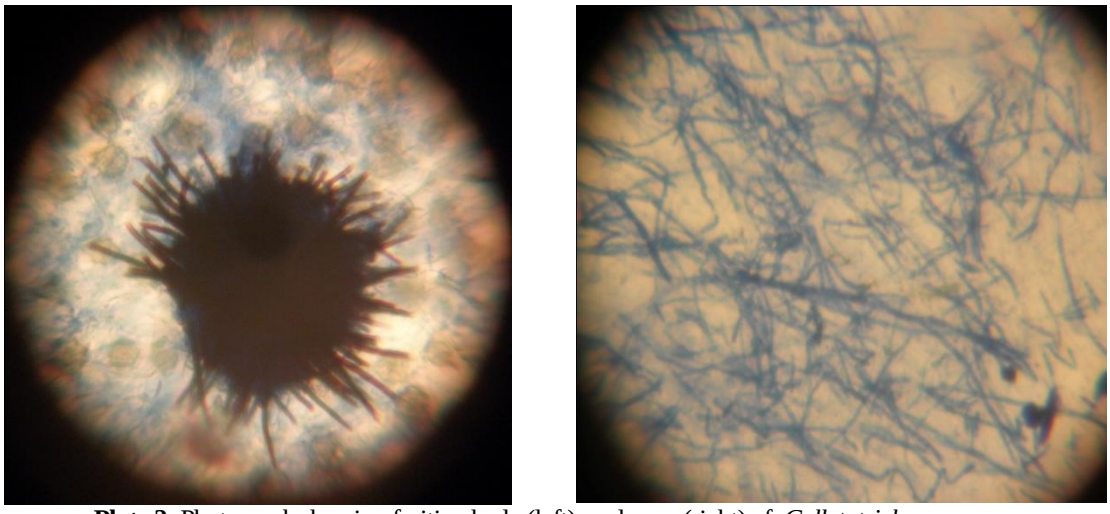

Plate 2: Photograph showing fruiting body (left) and spore(right) of *Colletotrichum musae*.

Diagnostic characteristics of (*Colletotrichum musae):*

It has orange color colony with scanty, white mycelia and dense orange conidial ooze, mycelium was hyaline and septate. Conidia are hyaline, one celled and straight (Plate 1). This pathogen causes anthracnose disease of banana. Anthracnose is characterized as small black speaks on fruit. The lesions increased in size and later become sunken and coalesced forming spots on the fruit surface (Plate 1).

Summary and Conclusion

The experiment was conducted at the laboratory, Department of Horticulture, Bangladesh Agricultural University, Mymensingh. The objectives of the experiment were to evaluate the pattern of shelf life and quality of banana cv. Amritasagar, Sabri and Champa under different promising postharvest treatments.

Parameters investigated were shelf life, total soluble solids, disease incidence, disease severity and causal pathogen. The results showed that the TSS, disease incidence and diseases severity increased during storage period. Postharvest treatments and variety caused showed highly significant variation to influences shelf life of bananas. Highly significant variations were observed among the different varieties of banana. The shelf lives of banana varieties Sabri, Champa and Amritasagar were 10.81, 10.11 and 9.00 days, respectively. From the varietal effects it was observed that longest shelf life was obtained in

Sabri than the others. The longest shelf life (16.25 days) was recorded in Sabri under low temperature storage condition followed by the Champa (14.56 days) under same storage condition.

Postharvest treatments and varieties caused significant variation in total soluble solids (TSS) content during storage. The highest total soluble solids contents (26.29%) was found in Sabri at the 9th day of storage and the lowest total soluble solids contents (12.22%) was found in Amritasagar at the 3rd day of storage. The maximum value of TSS (27.11% Brix.) was observed at the 6th day of storage under control condition. The variety Sabri had higher TSS content than that of Champa and Amritasagar. An increasing trend in TSS content was observed in all varieties at all ripening stages.

The disease severity and disease incidence were greatly influenced by postharvest treatments and varieties. The maximum (25.52%) disease severity was observed in Amritasagar at the 9th day of storage. The lowest disease level (0.38) was found in bananas which were stored at 15°C and highest disease levels (26.97) was found in fruits cooled at 5°C at the 9th days of storage. At the 12th day of storage all the treated fruits were completely damaged except modified atmosphere packaging with $KMnO_4$ and storage at 15°C. All the variety caused significant effect on the levels of disease severity but Sabri shows less disease severity in comparison to other varieties. At the 9th days Amritasagar showed the highest (78.06%) incidence but Sabri showed the lowest (70.83%) disease incidence. All the treatments exhibited significance differences in influencing disease incidence. Modified atmosphere packaging and storage at 15°C was showed lower disease incidence. Disease incidence was the lowest in Sabri than that of Amritasagar and Champa.

Considering the findings it may be concluded that significant variation existed due to the effects of different postharvest treatments and varieties in respect of prolongation of shelf life. The shelf life of banana could be extended up to 15.58 days at low storage temperature and up to 10.91 days due to modified atmosphere packaging with $KMnO_4$. The longer shelf life of banana with above mentioned treatments might be related to the slower changes in chemical components. However, for further study, investigation related to physiochemical changes like respiration rate, ethylene production, etc. should be considered for better understanding of the varied quality changes as influenced by variety and postharvest treatments.

References

Abdullah, H. M. A., M. A. Rohaya and H. Z. Zaipun. 1985. Physico- chemical changes during maturation and after ripening of bananas (*Musa sapientum* cv Embum). *MARDI Research Buletin,* 13(**3**): 341-347.

Amiruzzaman, M. 1990. Postharvest handling and processing of fruits and vegetables. In: Kitchen Gardening and Homestead Production Activities. CIRDAP Action Res. Series No.11, 22p.

Basel, R. M., K. Racicot. and A. G. Senecal. 2002. Long shelf life Banana storage using MAP storage coupled with postharvest MCP treatment. Online: 08.10.1011. Available from:http://ift.confex.com/ift/2002/techprogram/paper_13343htm

BBS (Bangladesh Bureau of Statistics). 2010. Yearbook of Agricultural statistics of Bangladesh. Bangladesh bureau of Statistics Division, Ministry of Planning, Government of People's Republic of Bangladesh.

Bhadra, S. and S. K. Sen. 1997. Postharvest storage of custard apple (*Annona squamosa L*) fruit var. LOCAL green under various chemical and wrapping treatments. *Envir. Ecol.*, 1(**4**):322-228.

Gomez, K. A. and A. A. Gomez. 1984. Statistical procedure for Agricultural research. John Wiley and Sons, Inc., New work. pp. 67-215.

Gupta, S. Y. and V. N. Pathak.1990. Epidemiology and Management of papaya fruit rots. *Phytopathologica*., 16(**2**) : 92-105.

Haque, M. A. 1988, Kalar Bagan (In Bengali). Banana Research Project, Bangladesh Agril. Univ., Mymensing, PP. 1-4.

Hassan, M. K. 2000. Studies of postharvest Behaviour of Bananas. Master Thesis, Department of Tropical Plant Science, School of Tropical Biology. James Cook University, Australia. p. 164.

Hassan, M. K. 2006. Constitutive Alkenyl Resorcinol's & Resistance to Postharvest Diseases in Mango. Phd. Thesis, School of Agronomy & Horticulture, The university of Quensland, Australia. p. 286.

Hassan, M. K., W. A. Shipton, R. Coventry. and C. Gardiner. 2004. Extension of banana shelf life. Australiasian PI. Path., 33: 305-308.

Hassan, M. K., W. A. Shipton, R. J. Coventry and C. P. Gardiner. 2005. Maintenance of fruit quality inorganically-grown bananas under modified atmosphere conditions. *Asian J. Plant Sci.,* 4(**4**): 409-412.

Hassan, M. K. 2010. A guide to postharvest handling of fruits and vegetables. Ali press, 21, Chhoto Bazar, Mymenshingh, 2200, Bangladesh. pp. 19-22.

Kader, A. A. 1992. Postharvest Technology of Horticultural Crops. 2nd ed. University of California.

Khader, M. A. J. B. M., K. Chellappan, P. K. Chattopadhy and O. Anchanam.1996. Banana. Fruits:Tropical and Subtropical. Eds. Bose,T.K. and S.K.Mitra. Naya Prokash,206 Bidhan Sarani, Calcutta, India.pp.130-134.

Rahman, M. M. and S. M. H. Kabir. 2006. Banana. BANGLAPEDIA: National Encyclopedia of Bangladesh. Online (October 2, 2011). Availablefrom:http://www.banglapedia.org/httpdocs/HT/B_0094.HTM

Rao, M. and R. Rao. 1979. Postharvest changes in banana cv. Robusta. *Indian J. Hort.,* 36; 387-393.

Salvador, A., T. Sanz and S. M. Fiszman. 2007. Changes in color and texture and their relationship with eating quality during storage of different dessert bananas. *Postharvest Biol. Technol.,* 43 (**3):** 319-325.

Sarker, H. N., M. A. Hasan and P. K. Chattopadhya. 1997. Influence on polythene packing of the post harvest stirage behavior of banana fruit. *Hort. J.,* 10(**1**): 3 139.

Scott, K. J. J. R., B. H. Wills. and L. E. Rippon. 1971. The use of seal polyethylene bunch covers during growth as a retardant to the ripening of bananas. Trop. *Agric. Trinidad,* 48(**2**): 163-165.