Academic Journal of Plant Sciences 6 (1): 19-31, 2013
ISSN 1995-8986

DOI: 10.5829/idosi.ajps.2013.6.1.327

Effects of Modified Atmosphere Packaging and Low Temperatures on the Physico-Chemical Changes and Shelf Life of Banana

[1]M.Z. Hossain, [1]M.K. Hassan, [2]G.N. Hasan and [3]M.R. Islam

[1]Department of Horticulture, Bangladesh Agricultural University (BAU), Bangladesh
[2]On farm Research Division,
Bangladesh Agriculture Research Institute (BARI), Patuakhali, Bangladesh
[3]Department of Biotechnology,
Patuakhali Science and Technology University, Dumki, Patuakhali-8602, Bangladesh

Abstract: The postharvest treatments included control, low temperatures (14 and 18°C) and plastic bags with or without perforations. Changes in different physico-chemical characteristics of fruits were studied during storage. The two factor experiment was laid out in completely randomized design with three replications of 10 fruits. Among the physico-chemical parameters, colour, firmness, total weight loss, pulp to peel ratio, moisture content, sugar content (total, reducing and non-reducing), TSS and titratable acidity increased but vitamin C and dry matter contents decreased with the progress of storage duration. At the 16th day of storage, maximum weight loss (24.64%), disease severity (47.77%), disease incidence (100%) were observed in control (untreated bananas), whereas significantly reduced levels of weight loss (10.21%) and (12.22%), disease severity (0.58%) and (0.64%), disease incidence (13.33%) and (18.16%) were recorded in bananas stored at 14°C and 18°C respectively. The lowest total sugar (16.29%), pulp to peel ratio (2.22), dry matter content (23.5%), titratable acidity (0.35%) and highest total sugar content (26.70%), pulp to peel ratio (3.87), dry matter content (47.3%), titratable acidity (0.50%) at the 16th day of storage in bananas held at 14 and 18°C temperature respectively. The shelf lives of (37.16) and (34.25 days) were observed in those bananas held at 14 and 18°C temperatures, respectively when wrapped with unperforated plastic bags. The untreated bananas have the shortest shelf life of (15.34 days).

Key words: Banana · Storage · Low Temperature · Fruit quality

INTRODUCTION

Banana (*Musa sapientum* L.) of the botanical family Musaceae is one of the major and commercially important fruit crops in the world trade. The major banana producing countries of the world are Brazil, India, the Philippines, Thailand, Mexico, Indonesia, Colombia and Costa-Rica. Presently, the total area coverage by banana production is 56 thousand hectares, with a total production of 909 thousand MT in Bangladesh [1]. Banana is a climacteric fruits and its ripening changes involve rapid conversion of starch into sugar as well as increased activity of the respiratory enzymes peroxidase and increased ethylene production [2] A considerable quantity of harvested bananas goes waste due to its perishable nature and loss in Bangladesh is estimated to be 25-50% [3]. The perishability of the fruit is attributed to adverse physiological changes, namely loss of weight due to respiration and transpiration, softening of flesh and loss of resistance to microbial attack. Postharvest losses of fruits per year including banana in Bangladesh has been estimated 0.226 million tons valued in Tk. 1356 million [4]. There are several loss reduction technologies have been devised to minimize the postharvest deterioration and extension of shelf life of banana. The technologies include modified atmosphere packaging, fruits storage under low temperature, controlled atmosphere packaging and use of chemical fungicides. It is imperative to embark on a comprehensive study and understand postharvest behaviour of banana fruits as affected by different

Corresponding Author: M.Z. Hossain, Department of Horticulture, Bangladesh Agricultural University (BAU), Bangladesh.

postharvest treatments to alleviate the postharvest losses, extend shelf life, maintain quality and ensure safety. Keeping the above facts in mind, the present investigation was designed to examine the efficacy of different low temperatures and modified atmosphere packaging to prolong banana shelf life maintaining quality.

MATERIALS AND METHODS

The experiment was conducted at the laboratories of the Departments of Horticulture, Biochemistry and Plant Pathology, Bangladesh Agricultural University (BAU), Mymensingh during the period from 18 September to 24 October 2007. The experiment consists of two factors:

Factor 1: Temperature:

T_1 = 14°C (fruits stored at 14°C temperature), T_2 = 18°C (fruits stored at 18°C temperature) and T_3 = Control (fruits stored at ambient condition)

Factor 2: MAP:

P_1 = Fruits stored without plastic bag (unwrapped control), P_2 = Fruits stored in unperforated plastic bags, P_3 = Fruits stored in perforated plastic bags having two perforations in each bag and P_4 = Fruits stored in perforated plastic bags having four perforations in each bag. The two-factor experiment was laid out in completely randomized design with three replications of 10 fruits.

In the experiment the following parameters were studied:

Color, firmness, weight loss, pulp to peel ratio, moisture content, dry matter content, total sugar, total soluble solids, vitamin C, titratable acidity, disease incidence, disease severity causal pathogens and shelf life

Weight losses of fruits as influenced by different postharvest treatments were estimated using the following formula:

$$\text{Percent weight loss (WL)} = \frac{\text{Initial weight of fruits (g)} - \text{Final weight of fruits (g)}}{\text{Initial weight of fruits (g)}} \times 100$$

The percentage of total sugar was determined by using the following formula:

$$\text{Total sugar (g/100g)} = \frac{\text{Amount of sugar obtained}}{\text{Weight of sample}} \times 100$$

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 was placed on the prism of the refractometer and total soluble solids content were recorded as%Brix from direct reading of the instrument.

The vitamin C content of the samples was calculated by using the following formula:

$$\text{Vitamin C content (mg/100 g)} = \frac{\text{Titre} \times \text{Dye factor} \times \text{Volume made up}}{\text{Volume made up} \times \text{Weight of sample}} \times 100$$

The disease incidence of banana was calculated by using the following formula:

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

Disease severity represents the percentage diseased portion of infected fruit and was measured based on eye estimation. Representative samples of diseased fruits were collected and taken to the laboratory of the Department of the Plant Pathology, Bangladesh Agricultural University, Mymensingh for isolation and identification of causal organisms.

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.

The collected data on various parameters were statistically analyzed using MSTAT Statistical Package. The significance of difference between the pairs of means was compared by least significant difference test at the 1% and 5% level of probability [5]. For the percentage data, arc-sine transformations were carried out to satisfy the assumption of ANOVA and statistical analysis were performed on the transformed- data.

RESULTS AND DISCUSSION

Colour Changes: At the 16th day of storage, the untreated bananas were completely blackened. In contrast, banana fruits held at 14° and 18°C temperatures had remarkably reduced rate of peel colour changes (Fig. 1). At the 8th day of storage, fruits stored without plastic bag had colour score 2, whereas those stored after being wrapped in unperforated plastic bag had minimum colour score (1) (Fig. 2). Considering the combined effects of temperature and modified atmosphere packaging delayed colour development of banana was observed when stored at 14°C temperature and wrapped with unperforated plastic bag (Table 1). The faster rate of

Table 1: Combined effects of temperature and modified atmosphere packaging on colour changes of banana during storage

		Colour score[a] at different days after storage						
Temp. × MAP		4	8	12	16	20	24	28
14ºC	P_1	1.00	1.00	1.12	3.52	6.33	7.00	7.00
	P_2	1.00	1.00	1.00	1.12	1.85	2.82	4.33
	P_3	1.00	1.00	1.37	2.00	2.77	3.60	4.63
	P_4	1.00	1.00	1.43	2.23	2.73	3.78	5.23
18ºC	P_1	1.00	1.00	1.52	3.35	6.44	7.00	7.00
	P_2	1.00	1.00	1.00	1.35	3.59	5.05	6.32
	P_3	1.00	1.22	1.57	2.16	4.72	6.10	7.00
	P_4	1.00	1.22	2.16	3.44	4.50	6.18	7.00
Control	P_1	1.00	4.61	6.16	7.00	-	-	-
	P_2	1.00	1.33	2.50	6.77	-	-	-
	P_3	1.00	6.10	6.61	7.00	-	-	-
	P_4	1.00	6.10	6.53	7.00	-	-	-
Level of significance		NS	**	**	**	**	**	**
LSD (0.05)		-	0.23	0.21	0.24	0.23	0.21	0.10
LSD (0.01)		-	0.31	0.28	0.32	0.31	0.29	0.49

P_1: Fruits stored without plastic bags (unwrapped Control), P_2: Fruits stored in unperforated plastic bags, P_3: Fruits stored in perforated plastic bags having 2 perforations in each bag and P_4: Fruits stored in perforated plastic bag having 4 perforations in each bag, [a] = colour score (1 = 0 to < 10% yellow, 2 = 10 to < 30 yellow, 3 = 30 to < 50% yellow, 4 = 50 to < 70% yellow, 5 = 70 to< 90% yellow, 6 = 90 to 100% yellow and 7 = blackened / rotten). No statistical analysis was performed in days 32 and 36. ** Significant at 1% level and ns: not-significant.

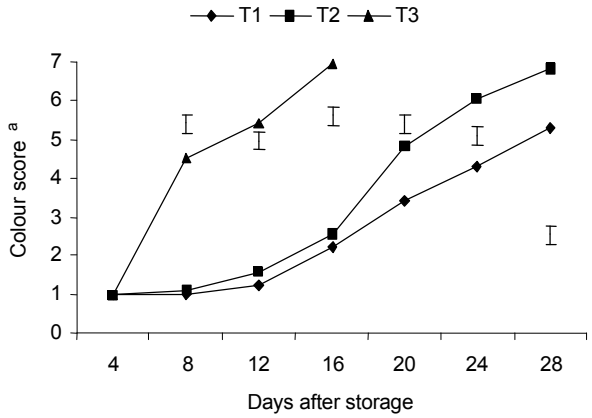

Fig. 1: Main effect of temperature on colour changes of banana at different days after storage. Vertical bars represent LSD at 5%level of significance.T_1: 14°C (fruits stored at 14°C temperature), T_2: 18°C (fruits stored at 18°C temperature) and T_3: Control (fruits stored at ambient condition). [a] = colour score

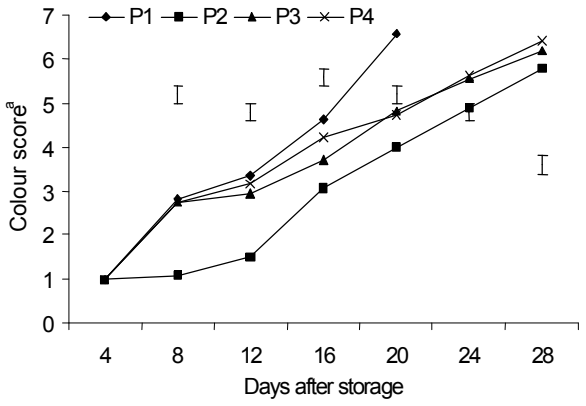

Fig. 2: Main effect of modified atmosphere packaging on colour changes of banana at different days after storage. Vertical bars represent LSD at 5% level of significance. P_1: Fruits stored without plastic bags (unwrapped Control), P_2: Fruits stored in unperforated plastic bags, P3: Fruits stored in perforated plastic bags having 2 perforations in each bag and P4: Fruits stored in perforated plastic bag having 4 perforations in each bag, [a] = colour score

colour change of banana under control treatment may be due to the rapid activity of some enzymes that are responsible for the colour changes of banana. The delay in ripening and senescence of banana fruits in the low temperature treatment may be attributed to the inhibition of different chemical changes like chlorophyll breakdown. The result of the present study also supports the findings of [6].

Changes in Firmness: At the 8th day of storage, the bananas stored at 14°C temperature remained firmness score (1) and which kept at 18°C temperature very low changes of firmness but those kept at ambient temperature had firmness score of 3 (Fig. 3). At 16th day

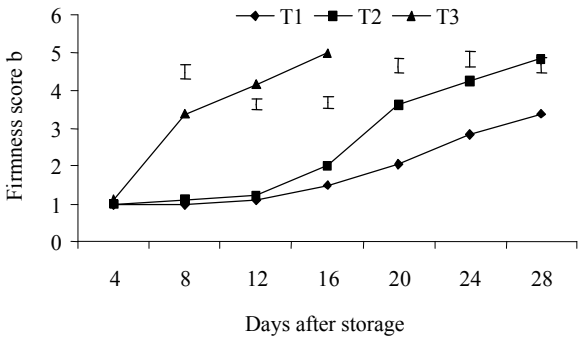

Fig. 3: Main effect of temperature on colour changes of banana at different days after storage. Vertical bars represent LSD at 5%level of significance.T_1: 14°C, T_2: 18°C and T_3: Control (fruits stored at ambient condition). [a] = colour score.

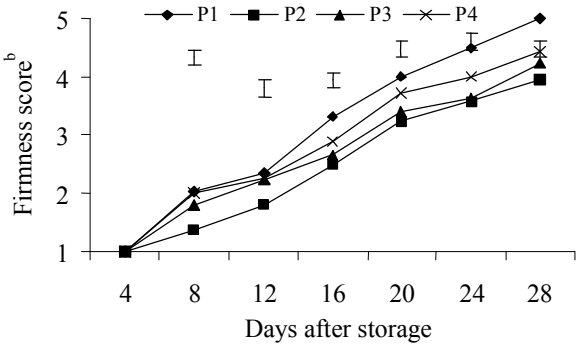

Fig. 4: Main effect of MAP on colour changes of banana at different days after storage. Vertical bars represent LSD at 5% level of significance. P_1: Fruits stored without plastic bags (unwrapped Control), P_2: Fruits stored in unperforated plastic bags, P3: Fruits stored in perforated plastic bags having 2 perforations in each bag and P4: Fruits stored in perforated plastic bag having 4 perforations in each bag, [a] = colour score

of storage, the bananas stored without plastic bag had firmness score of 4 (eating ripe) but those stored in unperforated plastic bags had firmness score of 2 (sprung) (Fig. 4). At 28th day of storage the bananas that were held at 14°C temperature in unperforated plastic bags (T_1P_2) showed delayed firmness changes of banana and firmness score had of 2.55 (Table 2). The firmness of banana changes due to conversion of starch into sugars. The results of the experiment support the findings of [7]. They described that creation an atmosphere with 11% CO_2 and 12% O_2 was the most effective treatment for delaying ripening of banana.

Weight Loss of Banana: At the 16th day of storage, the highest weight loss (24.64%) was found in fruits which were stored at ambient condition. But minimum weight loss (10.21 and 12.22%) occurred in bananas held at 14°and 18°C temperatures respectively (Table 3). At the 20th day of storage, the maximum weight loss (23.44%) was found in unwrapped fruits whereas the minimum weight loss (15.32%) was recorded in fruits held in unperforated plastic bags (Table 4). The combined effects of temperature and modified atmosphere packaging on total weight loss were statistically significant. At the 16th day of storage the maximum weight loss (26.33%) was found in bananas stored at ambient condition having no plastic wrapping. In contrast, remarkably reduced loss in weight (7.08%) was recorded in bananas those stored at 14°C temperature in treatment combination of T_1P_2 (Table 5).

Total Sugar Content of Banana Pulp: At the 4th day of storage, the lowest total sugar content (12.35%) was found in fruits pulp which kept at 14°C temperature and highest total sugar content (25.57%) was estimated in banana pulps which was stored at control condition (Table 6) The lowest total sugar content (4.79%) was found in fruit pulps held in unperforated plastic bags at the 4th day of storage and highest total sugar content (21.40%) was found in banana pulps stored at ambient condition (Table 7). At the 16th day of storage, the lowest (16.29%) total sugar content was estimated in the treatment combination of T_1P_2 and the highest total sugar content (26.70%) was observed in treatments combination of T31 (Table 8). In the present study, total sugar content increased during ripening and storage and this result was an agreement with the observation of [8].

Total Soluble Solids Content: The lowest total soluble solids content (9.52%) was found in fruit stored at 14°C temperature at the 4th day of storage and the highest total soluble solids content (25.28%) was estimated in banana kept at control condition at the 12th day of storage (Table 9). The maximum TSS value of (18.44%) and (18.25%) were recorded in control and plastic bags having 4 perforations at the 16th day of storage, whereas minimum TSS vale (9.62%) and (10.41%) were recorded in unperforated plastic bags and the plastic bags having two perforations respectively (Table 10). The highest total soluble solids content (27.16%) was observed in fruits of the treatment combination of T_3P_1 the at 12th day of storage and the lowest total soluble solids content (9.06%) was estimated in banana of

Table 2: Combined effects of temperature and modified atmosphere packaging on firmness changes of banana during storage

		Firmness score [b] at different days after storage						
Temperature × MAP		4	8	12	16	20	24	28
14[i]C	P_1	1.00	1.00	1.22	2.28	3.37	5.00	5.00
	P_2	1.00	1.00	1.00	1.05	1.30	1.94	2.55
	P_3	1.00	1.00	1.06	1.23	1.41	1.77	2.66
	P_4	1.00	1.00	1.13	1.43	2.04	2.66	3.28
18[i]C	P_1	1.00	1.00	1.35	2.66	3.22	4.50	5.00
	P_2	1.00	1.00	1.00	1.45	3.39	3.75	4.25
	P_3	1.00	1.17	1.24	1.72	3.78	3.50	5.00
	P_4	1.00	1.17	1.28	2.22	4.08	4.61	5.00
Control	P_1	1.00	3.38	4.22	5.00	-	-	-
	P_2	1.00	2.17	3.44	5.00	-	-	-
	P_3	1.22	3.93	4.40	5.00	-	-	-
	P_4	1.17	3.97	4.60	5.00	-	-	-
Level of significance		NS	**	**	**	**	**	**
$LSD_{(0.05)}$	-	0.22	0.18	0.18	0.23	0.24	0.23	
$LSD_{(0.01)}$	-	0.30	0.24	0.25	0.31	0.32	0.31	

P_1: Fruits stored without plastic bags (unwrapped Control), P_2: Fruits stored in unperforated plastic bags, P3: Fruits stored in perforated plastic bags having 2 perforations, P4: Fruits stored in perforated plastic bag having 4 Perforations, b= firmness score No statistical analysis was performed in days 32 and 36. ** Significant at 1% level and ns: not-significant.

Table 3: Main effect of temperature on weight loss of banana during storage

	Weight loss (%) at different days after storage						
Temperature	4	8	12	16	20	24	28
14°C	2.30(8.63)	4.07(11.46)	6.26(14.13)	10.21(18.39)	14.85(22.50)	17.71(24.73)	21.75(27.67)
18°C	2.64(9.33)	4.41(11.97)	7.46(15.74)	12.22(20.31)	16.84(24.09)	19.60(26.15)	24.04(29.25)
Control	3.94(11.41)	9.27(17.66)	17.91(25.00)	24.64(29.74)	-	-	-
Level of significance	**	**	**	**	**	**	**
$LSD_{(0.05)}$	0.57	0.45	0.54	0.43	0.22	0.24	0.19
$LSD_{(0.01)}$	0.76	0.61	0.73	0.59	0.30	0.32	0.25

Figures in the parenthesized arcsine transformed data. Statistical analysis has been performed on the transformed data. ** Significant at 1% level and ns = not-significant.

Table 4: Main effect of MAP on weight loss of banana during storage

	Weight loss (%) at different days after storage						
MAP	4	8	12	16	20	24	28
P_1	3.49(10.70)	7.85(16.18)	14.12(21.83)	19.83(26.29)	23.44(23.32)	25.75(27.90)	28.57(35.24)
P_2	2.42(8.85)	4.22(11.60)	8.38(16.13)	12.73(20.27)	15.32(14.50)	16.88(16.16)	18.87(20.84)
P_3	2.89(9.68)	5.69(13.38)	9.75(17.56)	14.46(21.75)	17.64(17.40)	19.37(20.85)	22.61(26.94)
P_4	3.03(9.93)	5.90(13.62)	9.92(17.63)	15.74(22.94)	18.71(18.23)	20.62(20.75)	23.88(28.30)
Level of significance	**	**	**	**	**	**	**
$LSD_{(0.05)}$	0.66	0.52	0.62	0.50	2.13	2.19	3.09
$LSD_{(0.01)}$	0.89	0.70	0.84	0.68	2.96	3.04	4.29

MAP= modified atmosphere packaging, P_1: Fruits stored without plastic bags (unwrapped Control), P_2: Fruits stored in unperforated plastic bags, P_3: Fruits stored in perforated plastic bags having 2 perforations, P_4: Fruits stored in perforated plastic bag having 4 perforations. Figures in the parenthesized arcsine transformed data and statistical analysis has been performed on the transformed data.

Table 5: Combined effects of temperature and modified atmosphere packaging on weight loss changes of banana during storage

		Weight loss (%) at different days after storage						
Temperature × MAP		4	8	12	16	20	24	28
14ºC	P_1	3.27(10.40)	6.52(14.77)	11.41(19.73)	16.10(23.64)	21.30(27.47)	24.91(29.93)	28.72(32.39)
	P_2	1.81 (7.63)	2.73 (9.50)	3.80 (11.21)	7.08 (15.43)	10.92(19.28)	13.58(21.61)	16.03(23.59)
	P3	1.97 (8.02)	3.48(10.75)	5.08 (13.02)	8.13 (16.56)	13.03(21.15)	15.30(23.01)	20.48(26.90)
	P4	2.18 (8.45)	3.55(10.84)	4.75 (12.57)	9.53 (17.97)	14.17(22.10)	17.06(24.40)	21.78(27.81)
18ºC	P_1	2.77 (9.56)	6.93(15.25)	10.51(18.90)	17.06(24.38)	22.7 (28.44)	26.00(30.65)	30.65(33.60)
	P_2	2.25 (8.62)	3.1 (10.24)	5.95 (14.09)	8.70 (17.15)	12.6 (20.80)	14.63(22.48)	18.15(25.20)
	P_3	2.73 (9.50)	3.66(11.02)	6.65 (14.93)	10.42(18.82)	15.03(22.80)	17.97(25.06)	22.48(28.29)
	P_4	2.82 (9.65)	3.88(11.36)	6.75 (15.05)	12.73(20.89)	17.00(24.34)	19.83(26.43)	24.90(29.92)
Control	P_1	4.4 (12.15)	10.11(18.53)	20.45(26.87)	26.33(30.86)	-	-	-
	P_2	3.22(10.31)	3.77(15.07)	15.42(23.10)	22.42(28.25)	-	-	-
	P_3	3.98 (11.5)	9.95(18.38)	17.53(24.73)	24.85(29.89)	-	-	-
	P_4	4.12(11.70)	10.27(18.67)	18.27(25.29)	24.97(29.97)	-	-	-
Level of significance		NS	**	**	**	**	**	**
$LSD_{(0.05)}$		-	0.89	1.07	0.86	3.69	3.79	5.35
$LSD_{(0.01)}$		-	1.21	1.45	1.17	5.13	5.27	7.44

P_1: Fruits stored without plastic bags (unwrapped Control), P_2: Fruits stored in unperforated plastic bags, P_3: Fruits stored in perforated plastic bags having 2 perforations, P_4: Fruits stored in perforated plastic bag having 4 perforations in each bag. Figures in the parenthesized arcsine transformed data. Statistical analysis has been performed on the transformed data. ** Significant at 1% level and ns: not-significant. No statistical analysis was performed in days 32 and 36.

Table 6: Main effect of temperature and on total sugar content of banana during storage

	Total sugar content at DAS			
Temperature	4	8	12	16
14°C	12.35	13.79	15.35	17.58
18°C	12.42	13.88	15.50	17.70
Control	17.81	19.65	22.20	25.57
Level of significance	**	**	**	**
$LSD_{(0.05)}$	0.05	0.06	0.17	0.14
$LSD_{(0.01)}$	0.07	0.07	0.23	0.19

** Significant at 1% level

Table 7: Main effect of modified atmosphere packaging on total sugar content of banana during storage

	Total sugar content at different days after storage			
MAP	4	8	12	16
P_1	14.79	16.74	18.75	21.40
P_2	13.47	14.80	16.27	18.34
P_3	14.24	15.57	17.84	20.71
P_4	14.27	15.80	17.88	20.69
Level of significance	**	**	**	**
$LSD_{(0.05)}$	0.06	0.06	0.19	0.16
$LSD_{(0.01)}$	0.08	0.09	0.26	0.22

P_1: Fruits stored without plastic bags (unwrapped Control), P_2: Fruits stored in unperforated plastic bags, P_3: Fruits stored in perforated plastic bags having 2 perforations, P_4: Fruits stored in perforated plastic bag having 4 perforations and ** Significant at 1% level.

Table 8: Combined effects of temperature and modified atmosphere packaging on total sugar content of banana during storage

		Total sugar content (%) at different days after storage			
Temperature × MAP		4	8	12	16
14ºC	P_1	13.08	15.03	16.68	18.70
	P_2	11.71	12.95	14.40	16.29
	P_3	12.29	13.56	15.15	17.76
	P_4	12.32	13.62	15.17	17.57
18ºC	P_1	13.13	15.07	16.75	18.79
	P_2	11.76	13.03	14.50	16.41
	P_3	12.37	13.67	15.33	17.74
	P_4	12.40	13.75	15.41	17.85
Control	P_1	18.17	20.11	22.82	26.70
	P_2	16.93	18.41	19.92	22.31
	P_3	18.06	20.02	23.03	26.63
	P_4	18.08	20.04	23.05	26.64
Level of significance		**	**	**	**
LSD $_{(0.05)}$		0.10	0.10	0.34	0.29
LSD $_{(0.01)}$		0.14	0.14	0.46	0.39

P_1: Fruits stored without plastic bags (unwrapped Control), P_2: Fruits stored in unperforated plastic bags, P_3: Fruits stored in perforated plastic bags having 2 perforations, P_4: Fruits stored in perforated plastic bag having 4 perforations and ** Significant at 1% level of significance.

Table 9: Main effect of temperature on total soluble solids content of banana during storage

	Total soluble solids content (%) at different days after storage			
Temperature	4	8	12	16
14°C	9.52	11.20	12.60	13.80
18°C	9.77	11.76	13.19	14.86
Control	11.81	19.65	25.28	24.15
Level of significance	**	**	**	**
LSD $_{(0.05)}$	0.27	0.43	0.41	0.38
LSD $_{(0.01)}$	0.37	0.59	0.56	0.52

** Significant at 1% level.

Table 10: Main effect of modified atmosphere packaging on total soluble solids content of banana during storage

	Total soluble solids content (%) at different days after storage			
MAP	4	8	12	16
P_1	10.89	15.44	18.21	18.44
P_2	9.62	12.87	15.95	17.08
P_3	10.41	14.14	16.84	17.15
P_4	10.53	14.36	17.10	18.25
Level of significance	**	**	**	**
LSD $_{(0.05)}$	0.32	0.50	0.48	0.44
LSD $_{(0.01)}$	0.43	0.68	0.65	0.60

MAP= modified atmosphere packaging, P_1: Fruits stored without plastic bags (unwrapped Control), P_2: Fruits stored in unperforated plastic bags, P_3: Fruits stored in perforated plastic bags having 2 perforations, P_4: Fruits stored in perforated plastic bag having 4 perforations and ** Significant at 1% level.

Table 11: Combined effects of temperature and modified atmosphere packaging on total soluble solids content of banana during storage

		Total soluble solids (%) at different days after storage			
Temperature × MAP		4	8	12	16
14ºC	P_1	9.83	12.40	13.56	15.03
	P_2	9.06	10.30	11.90	12.80
	P_3	9.55	10.93	12.36	13.63
	P_4	9.63	11.16	12.60	13.76
18ºC	P_1	10.11	12.46	13.90	15.63
	P_2	9.31	10.83	12.96	13.88
	P_3	9.76	11.83	12.80	14.76
	P_4	9.90	11.93	13.10	15.16
Control	P_1	12.73	21.46	27.16	24.66
	P_2	10.50	17.50	23.00	26.06
	P_3	11.93	19.66	25.36	23.06
	P_4	12.08	20.00	25.60	22.83
Level of significance		*	*	**	**
LSD $_{(0.05)}$		0.55	0.87	0.83	0.77
LSD $_{(0.01)}$		0.75	1.19	1.12	1.04

MAP= modified atmosphere packaging, P_1: Fruits stored without plastic bags (unwrapped Control), P_2: Fruits stored in unperforated plastic bags, P_3: Fruits stored in perforated plastic bags having 2 perforations, P_4: Fruits stored in perforated plastic bag having 4 perforations, * Significant at 5% level and ** Significant at 1% level.

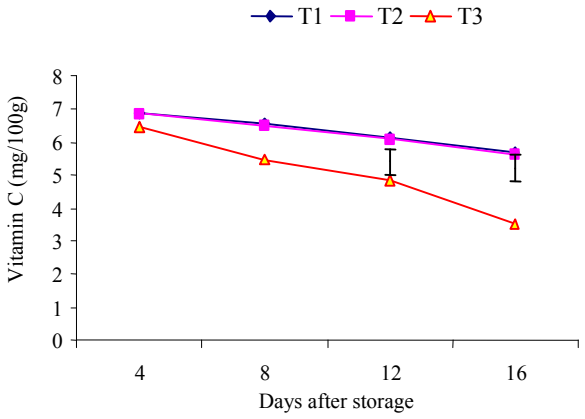

Fig. 5: Main effect of temperature on vitamin c content of banana at different days after storage. Vertical bars represent LSD at 5%level of significance.T_1: 14°C (fruits stored at 14°C temperature), T_2: 18°C (fruits stored at 18° C temperature) and T_3: Control (fruits stored at ambient condition).

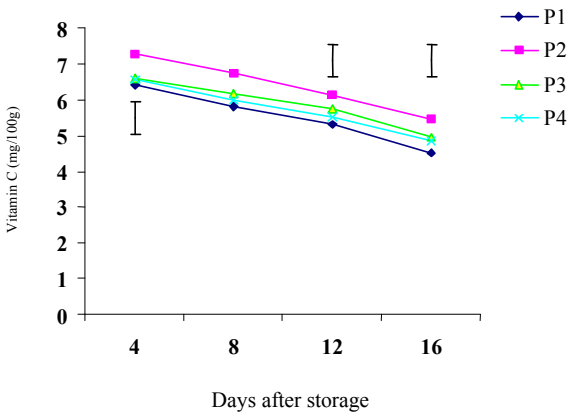

Fig. 6: Main effect of modified atmosphere packaging on colour changes of banana at different days after storage. Vertical bars represent LSD at 5% level of significance. P_1: Fruits stored without plastic bags (unwrapped Control), P_2: Fruits stored in unperforated plastic bags, P3: Fruits stored in perforated plastic bags having 2 perforations in each bag and P4: Fruits stored in perforated plastic bag having 4 perforations in each bag

treatment combination of T_1P_2 at the 4th day of storage (Table 11). Increase in TSS content as found in the present investigation.

Vitamin C Content: The lowest vitamin C content (3.52 mg/100g) was found in banana pulps which held at ambient condition and the highest vitamin C content (6.88 mg/100g) was estimated in fruits which stored at 14°C temperature at the 4th day of storage (Fig. 5). The highest vitamin C content (7.27 mg/100g) was recorded in fruits pulps which treated with upperforated plastic bags at the 4th day of storage and the lowest vitamin C content (4.53 mg/100g) in banana pulps which kept in control condition at the 16th day of storage (Fig. 6). The lowest vitamin C content (3.42 mg/100g) was estimated in the treatment combination of T_3P_1 at the 16th

Table 12: Combined effects of temperature and modified atmosphere packaging on vitamin C content of banana during storage

		Vitamin C content (mg/100g) at different days after storage			
Temperature × MAP		4	8	12	16
14ºC	P_1	6.50	6.05	5.54	5.11
	P_2	7.43	7.13	6.78	6.33
	P_3	6.79	6.58	6.24	5.73
	P_4	6.80	6.48	6.04	5.63
18ºC	P_1	6.46	6.00	5.48	5.05
	P_2	7.38	7.06	6.68	6.25
	P_3	6.77	6.50	6.16	5.66
	P_4	6.72	6.43	6.00	5.48
Control	P_1	6.33	5.43	4.95	3.42
	P_2	7.00	6.00	4.96	3.78
	P_3	6.25	5.40	4.86	3.46
	P_4	6.18	5.03	4.51	3.43
Level of significance		NS	NS	*	NS
$LSD_{(0.05)}$		-	-	0.53	-
$LSD_{(0.01)}$		-	-	0.72	-

MAP= modified atmosphere packaging, P_1: Fruits stored without plastic bags (unwrapped Control), P_2: Fruits stored in unperforated plastic bags, P_3: Fruits stored in perforated plastic bags having 2 perforations, P_4: Fruits stored in perforated plastic bag having 4 perforations, * Significant at 5% level and ns: non-significant.

Table 13: Main effect of temperature on disease incidence of banana during storage

	Disease incidence (%) at different days after storage						
Temperature	4	8	12	16	20	24	28
14°C	0.00	0.00(0.00)	0.00(0.00)	13.33(12.15)	22.16(19.94)	25.00(22.92)	49.75(48.51)
18°C	0.00	0.00(0.00)	4.00(6.32)	18.16(19.71)	40.08(36.66)	63.75(59.42)	87.41(78.66)
Control	0.00	46.50(40.59)	98.50(87.87)	100(89.96)	-	-	-
Level of significance	0.00	**	**	**	**	**	**
$LSD_{(0.05)}$	NS	5.85	5.76	6.10	9.81	9.21	4.10
$LSD_{(0.01)}$	-	7.93	7.81	8.27	13.30	12.49	5.55

Figures in the parenthesized arcsine transformed data. Statistical analysis has been performed on the transformed data.
** Significant at 1% level and ns = not-significant.

Table 14: Main effect of MAP on disease incidence of banana during storage

	Disease incidence (%) at different days after storage						
MAP	4	8	12	16	20	24	28
P_1	0.00	14.55(14.13)	31.33(27.58)	64.44(58.56)	96.22(85.99)	100.00(89.96)	100.00(89.96)
P_2	0.00	3.66(4.40)	10.44(30.37)	20.50(30.37)	33.33(30.36)	35.11(32.92)	59.00(55.32)
P_3	0.00	10.44(20.76)	20.00(32.92)	37.00(34.20)	40.67(36.33)	49.89(46.68)	77.67(71.48)
P_4	0.00	12.00(16.34)	22.00(35.48)	40.55(39.31)	46.11(35.89)	66.67(53.33)	79.56(65.93)
Level of significance	NS	**	NS	**	**	**	**
$LSD_{(0.05)}$	-	6.75	-	7.05	15.93	15.39	11.65
$LSD_{(0.01)}$	-	9.16	-	9.56	22.15	21.40	16.19

MAP= modified atmosphere packaging, P_1: Fruits stored without plastic bags (unwrapped Control), P_2: Fruits stored in unperforated plastic bags, P_3: Fruits stored in perforated plastic bags having 2 perforations, P_4: Fruits stored in perforated plastic bag having 4 perforations. Figures in the parenthesized arcsine transformed data. Statistical analysis has been performed on the transformed data, ns = not- significant and ** Significant at 1% level.

day of storage and the highest vitamin C content (7.43 mg/100g) was recorded at 14°C temperature with unperforated plastic bags in treatment combination of T_1P_2 (Table 12).

Disease Incidence: At the 16th day of storage the lowest disease incidence (13.33%) and (18.16%) were observed in banana which were stored at 14 and 18°C temperatures whereas the highest disease incidence levels (100%) were found in bananas stored at control condition (Table 13). The lowest disease incidence (3.66%) was recorded in bananas that were in wrapped with unperforated plastic bags and the maximum disease incidence (14.55%) in the unwrapped bananas at the 8th day of storage (Table 14). The minimum disease incidence (0.0%) was observed at the 12th day of storage in treatment combination of T_1P_2 (Table 15).

Table 15: Combined effects of temperature and modified atmosphere packaging on per cent disease incidence of banana during storage

		Disease incidence (%) at different days after storage					
Temp. × MAP		8	12	16	20	24	28
14°C	P_1	0.00	0.00	53.33(46.90)	88.66(78.07)	100.00(89.96)	100.00(89.96)
	P_2	0.00	0.00	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	27.33(31.22)
	P_3	0.00	0.00	0.00(0.00)	0.00 (0.00)	0.00 (0.00)	33.00(34.33)
	P_4	0.00	0.00	0.00(0.00)	0.00(0.00)	0.00(0.00)	38.66(38.35)
18°C	P_1	0.00	0.00 (0.00)	40.00(38.83)	100.00(89.96)	100.00(89.96)	100.0(89.9)
	P_2	0.00	0.00(0.00)	0.00(0.573)	0.00(0.57)	5.33(8.23)	49.66(44.78)
	P_3	0.00	5.33(8.23)	11.00(12.06)	22.00(18.48)	49.6(49052)	100.00(89.96)
	P_4	0.00	10.66(15.90)	21.66(27.39)	38.33(37.64)	100.00(89.96)	100.00(89.96)
Control	P_1	43.66(41.26)	94.00(81.59)	100.00(89.96)	-	-	-
	P_2	11.00(12.06)	100.00(89.96)	100.00(89.96)	-	-	-
	P_3	76.33(61.14)	100.00(89.96)	100.00(89.96)	-	-	-
	P_4	55.00(47.89)	100.00(89.96)	100.00(89.96)	-	-	-
Level of significance		**	NS	**	**	**	**
$LSD_{(0.05)}$		11.71	-	12.22	27.60	26.66	20.18
$LSD_{(0.01)}$		15.87	-	16.56	38.36	37.06	28.05

P_1: Fruits stored without plastic bags (unwrapped Control), P_2: Fruits stored in unperforated plastic bags, P_3: Fruits stored in perforated plastic bags having 2 perforations in each bag and P_4: Fruits stored in perforated plastic bag having 4 perforations. Figures in the parenthesized arcsine transformed data. Statistical analysis has been performed on the transformed data. * Significant at5% level ** Significant at 1% level and ns: not-significant.

Disease severity

Table 16: Main effect of temperature on disease severity of banana during storage

	Disease severity (%) at different days after storage						
Temperature	4	8	12	16	20	24	28
14°C	0.00	0.00(0.00)	0.00(0.00)	0.58(2.61)	1.40(3.84)	2.19(4.72)	6.07(13.22)
18°C	0.00	0.00(0.00)	0.04(1.01)	0.64(3.44)	2.02(6.12)	6.44(12.30)	27.56(29.91)
Control	0.00	2.09(7.63)	15.10(21.27)	47.77(43.54)	-	-	-
Level of significance	NS	**	**	**	**	**	**
$LSD_{(0.05)}$	-	1.03	2.38	2.38	0.84	0.91	2.41
$LSD_{(0.01)}$	-	1.40	3.22	3.23	1.14	1.23	3.27

Figures in the parenthesized arcsine transformed data. Statistical analysis has been performed on the transformed data but no statistical analysis was performed in days 32 and 36. ** Significant at 1% level and ns = not- significant.

Table 17: Main effect of MAP on disease severity of banana during storage

	Disease severity (%) at different days after storage						
MAP	4	8	12	16	20	24	28
P_1	0.00	0.96(3.63)	4.28(7.19)	19.77(21.51)	22.20(25.22)	27.29(30.06)	40.59(38.86)
P_2	0.00	0.18(1.33)	0.80(3.35)	8.13(10.22)	9.13(10.22)	10.23(10.74)	13.17(16.48)
P_3	0.00	0.66(3.07)	5.07(8.16)	17.27(16.08)	18.31(16.34)	20.20(18.76)	27.22(29.12)
P_4	0.00	0.98(3.66)	10.05(11.77)	20.12(18.31)	21.61(19.74)	23.49(21.24)	30.57(31.15)
Level of significance	NS	**	**	**	**	**	**
$LSD_{(0.05)}$	-	1.19	2.75	2.75	2.96	3.01	4.06
$LSD_{(0.01)}$	-	1.61	3.72	3.73	4.12	4.19	5.65

P_1: Fruits stored without plastic bags (unwrapped Control), P_2: Fruits stored in unperforated plastic bags, P_3: Fruits stored in perforated plastic bags having 2 perforations, P_4: Fruits stored in perforated plastic bag having 4 perforations. Figures in the parenthesized arcsine transformed data. Statistical analysis has been performed on the transformed data, ns = not- significant and ** Significant at 1% level.

Table 18: Combined effects of temperature and modified atmosphere packaging on per cent disease severity levels of banana during storage

		Disease severity (%) at different days after storage						
Temperature× MAP		4	8	12	16	20	24	28
14°C	P_1	0.00	0.00	0.00	2.33(8.74)	5.60(13.67)	8.77(17.20)	15.10(22.79)
	P_2	0.00	0.00	0.00	0.00(0.00)	0.00(0.00)	0.00(0.00)	2.50 (9.06)
	P_3	0.00	0.00	0.00	0.00(0.00)	0.00(0.00)	0.00(0.00)	3.33(10.49)
	P_4	0.00	0.00	0.00	0.00(0.00)	0.00(0.00)	0.00(0.00)	3.37(10.55)
18°C	P_1	0.00	0.00	0.00(0.00)	2.00(7.94)	6.00(14.14)	18.10(25.20)	51.67(45.95)
	P_2	0.00	0.00	0.00(0.00)	0.00(0.00)	0.00(000)	0.28(2.12)	3.61 (10.84)
	P_3	0.00	0.00	0.06(1.19)	0.17(1.73)	0.28(2.12)	2.94(9.78)	26.67(30.93)
	P_4	0.00	0.00	0.11(1.71)	0.39(3.54)	1.83(7.65)	4.47(12.18)	28.33(31.92)
Control	P_1	0.00	2.89(9.74)	12.77(20.45)	60.00(50.83)	-	-	-
	P_2	0.00	0.55(2.85)	2.42(8.90)	24.40(29.54)	-	-	-
	P_3	0.00	2.00(8.08)	15.16(22.72).	51.67(45.94)	-	-	-
	P_4	0.00	2.94(9.85)	30.05(33.02)	55.00(47.86)	-	-	-
Level of significance		NS	**	**	**	**	**	**
$LSD_{(0.05)}$		-	2.06	4.76	4.77	5.13	5.22	7.04
$LSD_{(0.01)}$		-	2.80	6.45	6.46	7.14	7.25	9.79

P_1: Fruits stored without plastic bags (unwrapped Control), P_2: Fruits stored in unperforated plastic bags, P_3: Fruits stored in perforated plastic bags having 2 perforations, P_4: Fruits stored in perforated plastic bag having 4 perforations. Figures in the parenthesized arcsine transformed data. Statistical analysis has been performed on the transformed data. ** Significant at 1% level and ns: not-significant.

At the 20th day of storage, the fruits held at ambient condition were completely damaged but the fruits stored at 14 and 18°C temperatures remained acceptable condition (Table 16). At the 12th day of storage, the highest disease severity (10.05%) was found in bananas that kept at ambient condition and the lowest disease severity levels (0.80%) was observed in bananas that stored with unperforated plastic bags. At the 16th day of storage, the maximum disease severity level (60%) was observed in the treatment combination of T_3P_1 (control×unwrapped) (Table 17). Whereas least disease severity (24.40%) was observed in treatment combination of T_1P_2 (Table 18). Increase in disease severity levels in the present investigation with the progress of storage duration was due to microbial attack and increased infections by aerobic and anaerobic pathogens.

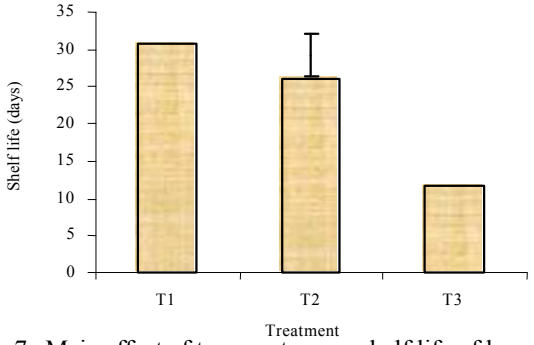

Fig. 7: Main effect of temperature on shelf life of banana. Vertical bar represents LSD at 5%level of significance.T_1: 14°C (fruits stored at 14°C temperature), T_2: 18°C (fruits stored at 18° C temperature) and T_3: Control (fruits stored at ambient condition).

Shelf Life: The longest shelf life (30.70 days) and (25.99 days) were recorded in bananas which were stored at low temperatures of 14°C followed by 18°C. The shortest shelf life (11.64 days) was observed in case of control treatment (Fig. 7). The longest shelf life (27.81 days) was observed in fruits held in unperforarted plastic bags followed perforated plastic bags having 2 perforations (24.44 days). By contrast, the shortest shelf life (15.34 days) was recorded in control fruits (Fig. 8). The longest shelf life (37.16 days) was recorded in fruits stored at 14°C temperature after being wrapped with unperforated plastic bags. The shortest shelf life (9.86 days) was noticed in treatment combination of T_3P_1 (Fig. 9). Sealed polythene bags had great impact on reducing water loss, decreasing O_2 concentration and increasing CO_2 concentration inside the plastic bags. Low humidity delays the internal synthesis of ethylene by preventing water loss. Low O_2 and high CO_2 reduce respiration rate, increase CO_2 and also inhibits the synthesis of ethylene production, thus it delays the pre-climacteric phase, delays degreening and extended shelf life [9].

At the 16th day of storage, fruits stored without plastic bags, the colour score became 5 but that stored with wrapped unperforated plastic bags, colour score became 3.5. At the 8th day of storage low temperatures 14

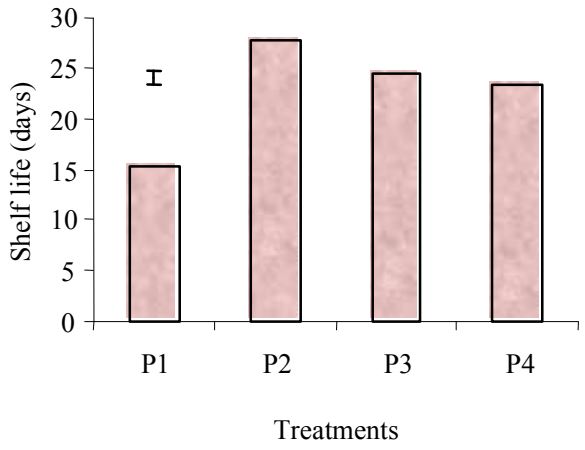

Fig. 8: Main effect of modified atmosphere packaging on shelf life of banana. Vertical bar represents LSD at 5% level of significance. P_1: Fruits stored without plastic bags (unwrapped Control), P_2: Fruits stored in unperforated plastic bags, P_3: Fruits stored in perforated plastic bags having 2 perforations and P_4: Fruits stored in perforated plastic bag having 4 perforations

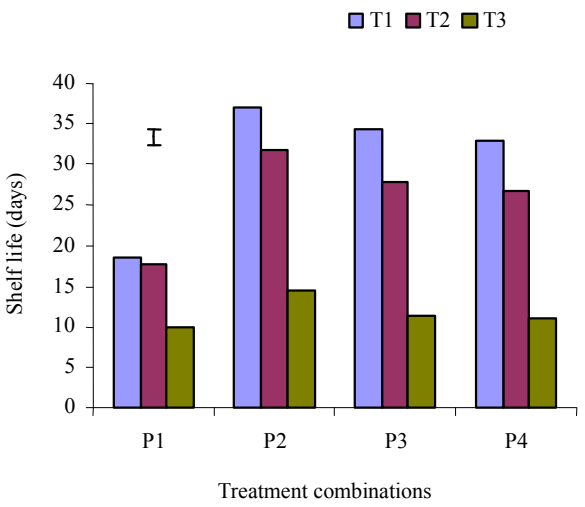

Fig. 9: Combined effects of modified atmosphere packaging and temperature on shelf life of banana. Vertical bar represents LSD at 5% level of significance. P_1: Fruits stored without plastic bags (unwrapped Control), P_2: Fruits stored in unperforated plastic bags, P3: Fruits stored in perforated plastic bags having 2 perforations in each bag and P4: Fruits stored in perforated plastic bag having 4 perforations in each bag.T_1: 14°C (fruits stored at 14°C temperature), T_2: 18°C (fruits stored at 18°C temperature) and T_3: Control (fruits stored at ambient condition).

and 18°C showed firmness score 1 and 2 whereas, the unwrapped control had firmness score (4). At the 20th day of storage the maximum weight loss (23.44%) was found in bananas which kept without plastic bags but minimum weight loss (15.32%) in fruits which treated with unperforated plastic bags. At the 4th day of storage the lowest total sugar content (12.35%) was noticed in fruit pulps treated with 14°C temperature and highest (25.57%) total sugar content was estimated in banana pulps which stored at control condition. The lowest TSS (9.52%) was found in fruits pulp that stored at 14°C temperature at the 4th day of storage and highest TSS (25.28%) was recorded in banana pulps which stored at control condition at the 12th day of storage. The lowest disease incidence (13.31%) and the second lowest incidence (18.16%) were found in bananas stored at 14 and 18°C temperatures, whereas the highest disease incidence levels (100%) were found in bananas stored at control condition at the 16th day of storage. At the 16th day of storage, the lowest disease severity (0.58%) was estimated in banana stored at 14°C temperature followed by (0.638%) were found in bananas stored at 18°C temperature whereas, the highest disease severity levels (47.77%) were observed in fruits kept at control condition. The highest self life (37.16 days) was recorded at 14°C temperature with unperforated plastic bags in treatment combination of T_1P_2 whereas the shortest self life (9.86 days) was found in unwrapped control condition in treatment combination of T_3P_1.

REFERENCES

1. BBS., 2006. Monthly Statistical Bulletin. June 2006. Bangladesh Bureau of Statistics. Statiatics Division, Ministry of planning Govt. of the people`s Republics of Bangladesh. Dhaka, pp: 137.
2. Rao, D.V.R. and B.S. Chundawat, 1986. Extension of shelf life of Lacatan bananas stored in cartoons: GAU. Res. J., 11(2): 26-31.
3. Amiruzzaman, M., 1990. Postharvest handling and processing of fruits and vegetables. In: Kitchen Gardening and Homestead Production Activities. CIRDAP Action Res. Series No. 11: 22.
4. Shams-ud-din, 1997. Importance and role of processing and preservation of food crops in Bangladesh. Proceeding of the National seminar on the "Role of Agricultural Engineering in National development" held at the Bangladesh Agril. Univ., Mymensingh, 15-16 May, 1997. Published by Agril. Eng. Div. BARC, Dhaka, pp: 22-32.

5. Robinson, J.C., 1996. A field comparison of ten Cavendish Sub group banana cultivars and selected (*Musa AAA*) over four crop cycles in the subtropics. J. Hort. Sci., 68(4): 511-521.
6. Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedure for Agricultural Research. John Wiley and Sons, Inc., New York, pp: 67-215.
7. Pesis, E.R., B. Arie, O. Feygenberg and F. Villamizar, 2005. Ripening of ethylene pretreated bananas is retarded using modified atmosphere and vacuum packaging, Dept. postharvest Sci. Fresh produce. Hort. Sci., 40(3): 726-731.
8. Purseglove, J.W., 1983. Tropical Crops. Monocotyledons. Longman Group Ltd. London, pp: 362.
9. Dadzie, B.K. and J.E. Orchard, 1997. Routine Postharvest screening of banana plantation Hybrids: Criteria and methods. INI BAP Technical Guidelines, International plant Genetic Resources Institute, Rome. Italy, pp: 1-63.