The Bioscan 12(1): 95-100, 2017
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.com

EFFECT OF MODIFIED AND ACTIVE PACKAGING ON SHELF LIFE AND QUALITY OF BANANA CV. *GRAND NAINE*

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KEYWORDS
Active packaging
Banana
Ethylene absorbent
Fruit quality
Shelf-life

Received on :
03.12.2016

Accepted on :
06.02.2017

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ABSTRACT

The present experiment was conducted at Post Harvest Laboratory, College of Horticulture, Dr. Y.S.R Horticultural University, Hyderabad during the year 2014 and 2015 with banana cv. Grand Naine where fruits were subjected to nine different treatments [T_1: Low density poly Ethylene (LDPE) film 150 gauge; T_2: LDPE + Ethylene Scrubber ($KMnO_4$) 5g Sachet; T_3: LDPE+ Humidity scrubber (silica gel) 2g sachet; T_4: LDPE + Ethylene Scrubber ($KMnO_4$) 5g Sachet+ Humidity scrubber (silica gel) 2g sachet; T_5: Poly propylene (PP) film 150 gauge; T_6: PP+ Ethylene Scrubber ($KMnO_4$) 5g Sachet; T_7: PP + Humidity scrubber (silica gel) 2 g sachet; T_8: PP+ Ethylene Scrubber ($KMnO_4$) 5g Sachet + Humidity scrubber (silica gel) 2 g sachet and T_9: Control (Fruits kept in open air)], each replicated thrice. All the fruits kept in different active packaging system delayed colour, texture, pulp to peel ratio and total soluble solids (TSS) content as compared to openly kept control banana. But, fruits packed with (LDPE + $KMnO_4$) recorded significantly lowest PLW (1.11 %) by maintaining significant amount of TSS (17.03° B), sugars (reducing, non reducing and total) in longest storage observation (on day 24) with a maximum shelf life up to 26.05 days compared to 9 days only for untreated fruits.

INTRODUCTION

Banana (*Musa* sp.), the "Poor man's apple" is grown throughout the tropics, subtropics and plays a key role in the economy of developing countries (Mulagund *et al.*, 2015) for its higher production potentiality from unit area in a short period of time. Banana fruit is a good source of vitamin A, C, B_1, B_2 and minerals like, magnesium, sodium, potassium, phosphorus and a fair source of calcium and iron. The sugar rich and low fat bananas have diverse uses as infant food, functional food, dessert and carbohydrate based staple foods (Mohapatra, 2009). India is the largest producer of banana (*Musa sp.*) in the world with a production of 28.45 million tonne from an area of 802.6 thousand ha and productivity of 37 mt/ha (NHB, 2015). Maximum production and productivity of banana acquired from Southern states in India due to presence of favourable climatic conditions (Kumbargire *et al.*, 2016). Out of large number of varieties grown in India, due to introduction of high yielding varieties like *Grand Naine*, the area of indigenous cultivar shrivelled to a great extent (Bhalerao *et al.*, 2011) and makes this new cultivar popular and dominant one for domestic and export trade in India. Besides the increasing production, major constraints and problems associated with post harvest handling of fresh banana are short shelf life under tropical climate (6–10 days) and lack of appropriate post harvest technologies for storage (Anon, 2007). Banana is a climacteric fruit with typical ethylene dependent ripening for which the shelf life of the banana deteriorates as soon as the climacteric peak is reached. Unlike many other fruits, banana is not a seasonal fruit in nature and is available in fairly large quantities throughout the year and records a post harvest losses as high as 30-40% (Patil and Hulmani, 1998). The benefits of increased production will not be realized unless it is duly accompanied by advanced storage, packaging and transport techniques. So, there is a need to find appropriate storage method to extend the storage life of banana to maintain the fruit quality for long distance transportation for domestic and export markets. Modified atmosphere packaging (MAP) is one of the potential preservation techniques (Mangaraj and Goswami, 2009) and is known to have great potentiality to extending the post harvest life of fruits and vegetables (Thompson, 1998). In recent time, as an innovative concept 'Active Packaging' is exceedingly accepted by food industry in which the package, the product, and the environment interact to prolong shelf life or enhance safety or sensory properties, while maintaining the quality of the product (Bhat, 2013). Components included in active packaging are capable of scavenging oxygen, absorbing carbon dioxide, ethylene and moisture and also remove unpleasant flavour. Active packaging perform traditional functions of packaging such as providing barriers to gases, moisture and vapour, preventing product contamination from outside, and making food handling and identification easy (De Kruijf et al., 2002). Thus, with an objective of curtailing post-harvest losses and extending availability of the fruit, an attempt was made in this experiment to evaluate the effectiveness of modified and active packaging system on fruit quality attributes and shelf-life extension of unripe green *'Grand Naine'* banana fruits under ambient condition.

MATERIALS AND METHODS

Sample preparation, experimental design and treatments

The present experiment on active packaging of banana cv. *Grand Naine* was carried out for two consecutive seasons of 2014-15. Mature banana fruits were obtained from farmers field located at Peddapur village of Medak district in Telangana, wherein pre-harvest spray schedules for effective control of major pests and diseases were strictly followed during fruit development and maturation up to the harvest of fruits. The fruit used for experiment were harvested after 110–115 days of inflorescence emergence. Selected fruits were then delatexed, water washed, sorted and graded by size, colour and weight. The individual hands were surface disinfected with Benomyl fungicide solution (1,000 ppm) for 5 min and dried under shade. The hands were randomly divided into different treatment groups. Each treatment group consisted of five uniform hands (15 to 18 fingers per hand). The experiment was designed in completely randomized design (CRD) at Post Harvest laboratory, College of Horticulture, DR. Y.S.R Horticultural University, Rajendranagar, Hyderabad, during the year 2014 and 2015 with following nine treatments [T_1: Low density poly Ethylene (LDPE) film 150 gauge; T_2: LDPE + Ethylene Scrubber ($KMnO_4$) 5g Sachet; T_3: LDPE + Humidity scrubber (silica gel) 2g sachet; T_4: LDPE + Ethylene Scrubber ($KMnO_4$) 5g Sachet + Humidity scrubber (silica gel) 2g sachet; T_5: Poly propylene (PP) film 150 gauge; T_6: PP + Ethylene Scrubber ($KMnO_4$) 5g Sachet; T_7: PP + Humidity scrubber (silica gel) 2 g sachet; T_8: PP + Ethylene Scrubber ($KMnO_4$) 5g Sachet + Humidity scrubber (silica gel) 2 g sachet and T_9: Control (Fruits kept in open air)] replicated thrice. Ethylene scrubber in granulated form was prepared by impregnating potassium permanganate in an inert matrix consisting of white cement and limestone power. The ethylene absorbing granules were packed in sachet form using HDPE woven fabric as 5 g units. The humidity scrubber Silica gel (2g) was taken in porous cellulose based sachets. Each unit package of banana was incorporated with one sachet each of ethylene and humidity absorbent. Low density poly ethylene bags (LDPE) of 150 gauge and Polypropylene bags of 150 gauge of size 40 x 30 cm without perforations were used for packing. The packages were stored at Room temperature of 25 ± 2ºC and relative humidity (RH) of 65-70%. Observations were recorded at 3 days interval upto 24th day of harvesting.

Data collection and observation recording

To determine internal and external quality parameters of banana using two hand sample per treatment, fruit samples were drawn periodically at 3, 6, 9, 12, 15, 18, 21 and 24 days of storage. Physiological loss in weight (PLW) was calculated as cumulative % loss in weight based on the initial fruit weight (before storage) and loss of weights recorded at the time of periodical sampling during storage (Waskar et al., 1999). A table top penetrometer was used to record the fruit firmness in kg/cm^2. Pulp to peel ratio of fruit were determined by dividing the weights of pulp to peel of a particular date, taken at regular intervals of time. The peel colour of fruit marked with visual observation and given colour status of green, greenish yellow, yellow with green tips only, uniform yellow, yellow with small spots, yellow with brown spots and yellow with big black spots as stated before as suggested by Patel (2003). Fruit spoilage determined based on visual symptom of shrivelling of fruit, hardening of the rind, fungal infection and subsequent rotting and percent fruit determined using following formula (Mandal et al., 2016):

$$\text{Fruit spoilage\%} = \frac{\text{No.of spolied fruits}}{\text{Total no.of fruits}} \times 100$$

The shelf life of fruit expressed as mean number of days, was assessed by recording the number of days required to make more than 50 percent fruit unfit for consumption and considered as end of shelf life in that particular treatment.

Determination of bio-chemical properties

The total soluble solids was estimated using digital refractometer (ATAGO, RX 5000, Tokyo, Japan) and was expressed as °Brix. Titrable acidity were determined by titrating 5 mL of juice against 0.1 N NaOH and expressed as % value. Total sugars, reducing sugars and non-reducing sugars were determined according to the method explained by Khan et al. (2009) and were expressed as %.

Statistical analysis

The collected data were analyzed statistically by the analysis of variance (ANOVA) technique using the SAS 9.3 version (SAS Institute Inc., 2011). The ANOVA of different quality parameters of banana across the years revealed a non-significant variation within the years as well as year × quality parameters interactions at $p \leq 0.05$. The homogeneity of error variance was tested using Bartlett's 'chi-square' test. As the error variance was homogeneous, pooled analysis was done. For comparison of 'F' values and computation of critical difference (CD) at 5% level of significance, Fisher and Yates' table were consulted.

RESULTS AND DISCUSSION

Physiological loss in weight (%)

The data on physiological loss in weight (PLW) as significantly influenced by various treatments and is presented in Table 1. PLW in banana fruit packed following active packaging methods was lower compared to unwrapped and openly kept control fruits (Table 1). It is evident from the Table 1 that during the storage period of 3rd, 6th, 9th and 12 day lowest PLW was recorded in T_2 (0.06, 0.13 and 0.18 and 0.41 %) followed by T_6 (0.08, 0.16, 0.23 and 0.50 %) while highest PLW was recorded in T_9 *i.e* control (8.53, 14.94, 18.17 % and nil). The reduction in PLW among treated green banana could be due to the selective permeability characteristics of LDPE packaging films against water vapour (Kudachikar et al., 2011) and efficacy of $KMnO_4$ as an ethylene scrubber to prevent injury from high levels of CO_2 or depletion of O_2 (Borkar et al., 2008). A similar trend in changes of PLW in banana treated with active

Table 1: Effect of active packaging methods on pulp to peel ratio and spoilage (%) of banana cv. *Grand Naine*

Treatments	PLW %								Fruit firmness (kg/cm^2)							
	3rd day	6th day	9th day	12th day	15th day	18th day	21st day	24th day	3rd day	6th day	9th day	12th day	15th day	18th day	21st day	24th day
T_1	0.53	0.60	0.98	1.80	*	*	*	*	5.11	4.19	1.69	1.24	*	*	*	*
T_2	0.06	0.13	0.18	0.41	0.60	0.93	1.11	1.27	5.28	5.09	4.73	4.15	3.65	3.15	2.55	1.47
T_3	0.17	0.25	0.34	0.74	0.94	1.25	*	*	5.08	4.73	3.67	3.05	2.55	1.35	*	*
T_4	0.11	0.20	0.31	0.52	0.74	1.06	1.32	*	5.12	4.74	4.15	3.65	3.38	2.57	1.36	*
T_5	0.50	0.69	1.15	1.90	*	*	*	*	5.08	4.15	1.66	1.15	*	*	*	*
T_6	0.08	0.16	0.23	0.50	0.65	0.98	1.16	1.30	5.25	5.05	4.67	4.05	3.45	2.76	1.83	1.30
T_7	0.18	0.27	0.39	0.80	1.15	1.32	*	*	5.06	4.65	3.61	3.00	2.46	1.32	*	*
T_8	0.13	0.23	0.34	0.57	0.79	1.16	1.39	*	5.11	4.70	4.11	3.60	3.35	2.51	1.32	*
T_9	8.53	14.94	18.17	*	*	*	*	*	3.50	1.95	0.87	*	*	*	*	*
S.Em±	0.008	0.01	0.02	0.005	0.02	0.01	0.009	0.01	0.05	0.02	0.02	0.02	0.02	0.02	0.01	0.01
CD at 0.05%	0.02	0.04	0.08	0.01	0.07	0.05	0.02	NS	0.15	0.07	0.06	0.08	0.08	0.06	0.03	NS

T_1 – Low density poly Ethylene (LDPE) film 150 gauge, T_2 - LDPE + Ethylene Scrubber ($KMnO_4$) 5g Sachet, T_3 - LDPE + Humidity scrubber (silica gel) 2 g sachet, T_4- LDPE + Ethylene Scrubber ($KMnO_4$) 5g Sachet + Humidity scrubber (silica gel) 2g sachet, T_5 - Polypropylene (PP) film 150 gauge, T_6 - PP + Ethylene Scrubber ($KMnO_4$) 5g Sachet, T_7 - PP + Humidity scrubber (silica gel) 2g sachet, T_8 - PP + Ethylene Scrubber ($KMnO_4$) 5g Sachet + Humidity Scrubber (silica gel) 2g sachet, T_9 - Control (without any treatment); Asterisk marks (*) denotes the end of shelf life in that particular date.

Table 2: Effect of active packaging methods on pulp to peel ratio and spoilage (%) of banana cv. *Grand Naine*

Treatments	Pulp to peel ratio								Spoilage (%)							
	3rd day	6th day	9th day	12th day	15th day	18th day	21st day	24th day	3rd day	6th day	9th day	12th day	15th day	18th day	21st day	24th day
T_1	1.61	2.14	2.62	3.14	*	*	*	*	0	5.11	12.84	49.05	73.35	*	*	*
T_2	1.32	1.37	1.42	1.54	2.00	2.21	2.45	2.70	0	0	0	0	4.12	11.02	23.00	45.00
T_3	1.58	1.75	1.92	2.15	2.82	3.12	*	*	0	0	5.01	12.55	26.00	49.05	71.00	*
T_4	1.41	1.67	1.75	1.90	2.12	2.30	2.60	*	0	0	0	5.10	12.00	27.05	48.50	74.00
T_5	1.73	2.16	2.67	3.15	*	*	*	*	0	4.11	12.85	49.95	74.05	*	*	*
T_6	1.35	1.42	1.54	1.82	2.02	2.27	2.50	2.90	0	0	0	0	5.35	13.05	28.00	48.00
T_7	1.63	1.77	1.97	2.20	2.87	3.17	*	*	0	0	5.10	12.56	27.02	50.00	76.00	*
T_8	1.41	1.72	1.83	1.92	2.17	2.32	2.68	*	0	0	0	5.03	12.55	27.50	50.00	76.00
T_9	1.94	2.25	3.08	*	*	*	*	*	5.35	27.58	47.56	76.02	*	*	*	*
S.Em ±	0.01	0.01	0.01	0.01	0.01	0.01	0.02	*	0.01	0.32	0.08	0.02	0.47	0.02	0.74	0.57
CD at 0.05%	0.05	0.05	0.04	0.05	0.04	0.04	0.08	*	NS	0.97	0.24	0.06	1.42	0.08	1.68	1.91

T_1 – Low density poly Ethylene (LDPE) film 150 gauge, T_2 - LDPE + Ethylene Scrubber ($KMnO_4$) 5g Sachet, T_3 - LDPE + Humidity scrubber (silica gel) 2 g sachet, T_4- LDPE + Ethylene Scrubber ($KMnO_4$) 5g Sachet + Humidity scrubber (silica gel) 2g sachet, T_5 –Polypropylene (PP) film 150 gauge, T_6 - PP + Ethylene Scrubber ($KMnO_4$) 5g Sachet, T_7 - PP + Humidity scrubber (silica gel) 2g sachet, T_8 - PP + Ethylene Scrubber ($KMnO_4$) 5g Sachet + Humidity Scrubber (silica gel) 2g sachet, T_9 - Control (without any treatment); Asterisk marks (*) denotes the end of shelf life in that particular date.

packaging practices was also reported by Kudachikar *et al.* (2007).

Fruit firmness

A significant variation in fruit firmness of banana was observed that received different post -harvest treatments (Table 1). The result showed reduction in fruit firmness steadily over the period of storage. Fruits kept in perforated polyethylene bag along with $KMnO_4$ treatment (T_2) remained the most firm (4.73 kg/cm^2) followed by fruits packed in Polypropylene + $KMnO_4$ (T_6), while minimum value (0.87 kg/cm^2) of firmness recoded for control fruits at 9th day of storage. The steady reduction in fruit firmness during the storage period is a complex natural process of ripening of almost all fleshy fruits as a result of biochemical changes of the cellular structure (Dharmasenal and Kumari, 2005). With advance in ripening, the cell walls broken, reduction in the cohesion of the middle lamella due to the solubilization of the pectic substance (Smith *et al.,* 1989) all of which result in softening of the fruits. Accordingly, the variation observed in fruit firmness in this study could be attributed to the direct and indirect effects of the treatments on the rate of respiration and ripening. The effect of polyethylene or polypropylene bag in delaying loss of firmness compared to the open air could be due to modified atmosphere created by using these packaging materials that reduced the rate of respiration and retarded tissue break down during slow ripening (Kotecha and Babasaheb, 1995). The effects of Polyethylene and $KMnO_4$ on fruit firmness coincide with the results obtained by Jobling (2000) and Shashirekha *et al.* (2007).The delay in firmness of fruit stored in polyethylene bag in combination with ethylene absorber $KMnO_4$ may be due to reaction of $KMnO_4$ with ethylene which produces carbon dioxide and water, thus limiting the role of ethylene on ripening (Jobling, 2000).

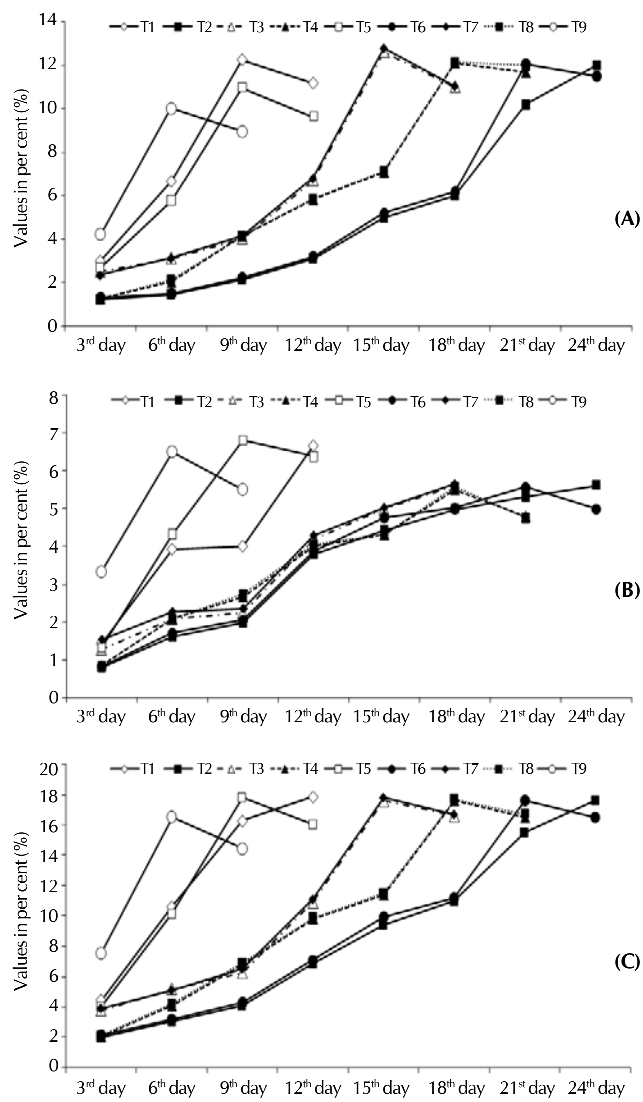
Pulp to peel ratio

There was significant ($P \leq 0.05$) variation in pulp to peel ratio of the banana fruits subjected to different postharvest treatments throughout the storage period (Table 2). Gradual increase of this ratio was recorded for banana treated with T_2 (LDPE + $KMnO_4$) and T_6 (PP + $KMnO_4$) upto 24th day of storage but at 12th day of storage maximum value (3.15 and 3.14) of this ratio was showed by fruits kept in Polypropylene (T_5) followed by LDPE (T_1) films, respectively. For untreated fruits a steady uplift of pulp to peel ratio from 1.94 to 3.08 recorded during 3rd and 9th day; but during same period of storage lowest increasement of (1.32 to1.42) recorded in T_2. Our results are in conformity of the results reported by Borkar *et al.* (2008) and Kudachikar *et al.* (2007) in active packaging of different varieties of banana. This sudden and slow rise in pulp to peel ratio in untreated and treated fruits could be due to osmotic transfer of moisture from peel to pulp at a faster and comparably

Table 3: Effect of active packaging methods on shelf life and peel colour of banana cv. *Grand Naine*

Treatments	Shelf life (days)	Peel colour 3rd day	6th day	9th day	12th day	15th day	18th day	21st day	24th day
T_1	13	Green	Greenish yellow	Yellow with green tip	Yellow with small spots	*	*	*	*
T_2	26.05	Green	Green	Green	Greenish yellow	Greenish yellow	Yellow with green tip	Uniformyellow	Yellow with small spots
T_3	19.08	Green	Green	Greenish yellow	Yellow with green tip	Uniformyellow	Yellow with small spots	*	*
T_4	22.06	Green	Green	Green	Greenish yellow	Yellow with green tip	Uniformyellow	Yellow with small spots	*
T_5	12.00	Green	Greenish yellow	Yellow with green tip	Yellow with small spots	*	*	*	*
T_6	25.07	Green	Green	Green	Greenish yellow	Greenish yellow	Yellow with green tip	Uniformyellow	Yellow with brown spots
T_7	18.00	Green	Green	Greenish yellow	Yellow with green tip	Uniformyellow	Yellow with small spots	*	*
T_8	21.00	Green	Green	Green	Greenish yellow	Yellow with green tip	Uniformyellow	Yellow with small spots	*
T_9	9.00	Greenish yellow	Yellow with green tip	Yellow with small spots	Yellow with black spot	*	*	*	*
S.Em±	0.43								
CD at 0.05%	1.29								

T_1 – Low density poly Ethylene (LDPE) film 150 gauge, T_2 – LDPE + Ethylene Scrubber ($KMnO_4$) 5g Sachet, T_3 – LDPE + Humidity scrubber (silica gel) 2 g sachet , T_4-LDPE + Ethylene Scrubber ($KMnO_4$) 5g Sachet + Humidity scrubber (silica gel) 2g sachet, T_5 –Polypropylene (PP) film 150 gauge, T_6 – PP + Ethylene Scrubber ($KMnO_4$) 5g Sachet, T_7 – PP + Humidity scrubber (silica gel) 2g sachet, T_8 – PP + Ethylene Scrubber ($KMnO_4$) 5g Sachet + Humidity Scrubber (silica gel) 2g sachet, T_9 – Control (without any treatment); Asterisk marks (*) denotes the end of shelf life in that particular date.



T_1 - Low density poly Ethylene (LDPE) film 150 gauge, T_2 - LDPE + Ethylene Scrubber ($KMnO_4$) 5g Sachet, T_3 - LDPE + Humidity scrubber (silica gel) 2 g sachet , T_4- LDPE + Ethylene Scrubber ($KMnO_4$) 5g Sachet + Humidity scrubber (silica gel) 2g sachet, T_5 -Polypropylene (PP) film 150 gauge, T_6 - PP + Ethylene Scrubber ($KMnO_4$) 5g Sachet, T_7 PP + Humidity scrubber (silica gel) 2g sachet, T_8 - PP + Ethylene Scrubber ($KMnO_4$) 5g Sachet + Humidity Scrubber (silica gel) 2g sachet, T_9 - Control (without any treatment)

Figure 1 (A-C): Effect of active packaging methods on reducing sugar (%), non-reducing sugar (%) and total sugar (%) of banana cv. Grand Naine

at slow rate during storage, respectively (Kudachikar *et al.*, 2011).

Colour development

The colour change in banana peel during storage has shown significant difference among the treatments on each sampling date (Table 3). Initially, the banana fruits were greenish but subsequently on their gradual ripening, they turned greenish yellow with green tips, uniform yellow, yellow with small spots and finally yellow with black spots during the storage. In this experiment, fastest colour change was observed in untreated fruits (on 12th day of storage fruits reached to final stage i.e. yellow with black spot) than other treated fruits. Late

Table 4: Effect of active packaging methods on TSS (^{0}B) and Acidity (%) of banana cv. *Grand Naine*

Treatments	TSS (^{0}B)								Acidity (%)							
	3rd day	6th day	9th day	12th day	15th day	18th day	21st day	24th day	3rd day	6th day	9th day	12th day	15th day	18th day	21st day	24th day
T_1	6.13	14.40	18.05	20.12	*	*	*	*	1.00	0.71	0.61	0.50	*	*	*	*
T_2	4.02	5.02	5.32	5.68	10.13	14.03	17.03	22.10	1.05	1.02	0.94	0.84	0.70	0.61	0.50	0.44
T_3	6.03	7.12	14.12	17.12	22.12	20.12	*	*	1.04	0.94	0.71	0.54	0.47	0.41	*	*
T_4	5.32	5.45	6.12	7.12	14.23	22.08	20.22	*	1.05	0.96	0.86	0.74	0.56	0.47	0.41	*
T_5	6.17	14.67	20.12	18.12	*	*	*	*	0.97	0.69	0.58	0.47	*	*	*	*
T_6	4.32	5.12	5.62	6.32	13.10	17.22	22.12	20.10	1.04	0.98	0.92	0.81	0.68	0.53	0.47	0.40
T_7	6.12	7.22	14.29	17.32	22.23	20.42	*	*	1.02	0.91	0.69	0.52	0.44	0.39	*	*
T_8	5.34	5.58	6.53	7.56	15.12	22.12	20.13	*	1.04	0.94	0.84	0.69	0.53	0.43	0.37	*
T_9	14.50	20.13	18.18	*	*	*	*	*	0.73	0.51	0.40	*	*	*	*	*
S.Em±	0.01	0.01	0.02	0.02	0.01	0.02	0.01	-	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-
CD at 0.05%	0.05	0.03	0.06	0.07	0.05	0.06	0.04	-	0.02	0.04	0.02	0.02	0.02	0.02	0.02	-

T_1 – Low density poly Ethylene (LDPE) film 150 gauge, T_2 – LDPE + Ethylene Scrubber ($KMnO_4$) 5g Sachet, T_3 – LDPE + Humidity scrubber (silica gel) 2 g sachet , T_4-LDPE + Ethylene Scrubber ($KMnO_4$) 5g Sachet + Humidity scrubber (silica gel) 2g sachet, T_5 –Polypropylene (PP) film 150 gauge, T_6 – PP + Ethylene Scrubber ($KMnO_4$) 5g Sachet, T_7 – PP + Humidity scrubber (silica gel) 2g sachet, T_8 – PP + Ethylene Scrubber ($KMnO_4$) 5g Sachet + Humidity Scrubber (silica gel) 2g sachet, T_9 – Control (without any treatment); Asterisk marks (*) denotes the end of shelf life in that particular date.

development of consumer's preferred greenish yellow colour in fruit obtained from banana packed with T_2 (LDPE + $KMnO_4$) and T_6 (PP + $KMnO_4$) followed by T_4 (LDPE + $KMnO_4$ + Silica gel) on 15th and 12th day of storage, respectively. Good marketable colour for long period of time upto 21th day of storage also maintained in the above two treatments i.e. T_2 and T_6. Same pattern of peel colour development of banana in modified atmospheric storage reported by Zewter *et al.* (2012) and Salvador *et al.* (2006). Delay in colour development and retention of chlorophyll could be due to decreased metabolic processes responsible for chlorophyll pigments degradation and biosynthesis of carotenoids pigments in the peel portions of green banana treated with treatments LDPE/ PP, $KMnO_4$ and Silica gel, under elevated CO_2 levels due to active storage conditions (Kudachikar *et al.,* 2011).

Spoilage (%) and shelf life

The data presented in Table 2 and 3 indicates the significant difference in percent spoilage and shelf life of banana fruits stored in different packaging materials. At 12th day storage untreated fruits attained 100% spoilage followed by T_5 (PP film) and T_1 (LDPE film) with 49. 95% and 49.05 % fruit spoilage respectively, while on the same day no fruits spoiled in T_2 (LDPE + $KMnO_4$) and T_6 (PP + $KMnO_4$). Minimum spoilage in banana even in storage of 24th day found in T_2 (45%) followed by T6 (48%). In accordance with the above result for spoilage percent of fruit, extended shelf life of banana also observed in case of T_2 (26.05 days) which was statistically at par with T_6 (25.07 days) followed by T_4 (22.06 days) and T_8 (21.00 days). But, minimum storage period recorded in T_9 (9.00 days) followed by T_5 (12.00 days) and T_1 (13.00 days). The result of percent spoilage and shelf life of banana fruit in this study is in agreement with previous report of Zewter *et al.* (2012) and Dong *et al.* (2002).The combined effect of the packaging material and ethylene absorbers in producing minimum spoiled fruit as well extended shelf life of banana could be attributed to partly to the moisture conservation by the polyethylene bags around the produce to reduce moisture loss, and shrivelling of the banana fruit, to cut off the concentration of ethylene and enzymatic activity and consequently slowing down the rate of respiration (Zewter *et al.,* 2012).

TSS and titratable acidity

Significant change in TSS and titratable acidity was observed in banana treated with different packaging materials and chemicals (Table 4). Fruits kept in open air showed a faster increment in their TSS content of 14.5 °Brix on day 3 to 18.18 °Brix on day 9 whereas banana treated with T_4 was slowest to reach the TSS peak (increasing from 4.02 °Brix on day 3 to 22.10 °Brix on day 24) followed by T_6 (increasing from 4.32 ºBrix on day 3 to 20.10 ºBrix on day 24). But, titratable acidity content decreased gradually with the passage of the storage period in all the treatments (Table 4). More rapid decline in acidity content observed in untreated fruits (declining from 0.73% on day 3 to 0.40% on day 9) whereas fruits treated with T_6 took longest time to reach minimum acidity (0.40% on day 24) followed by T_2 (0.44% on day 24).

The observed increment in TSS and rapid fall off acidity content of fruits placed in open air is an indication of high respiration rate and ripening thereby resulting in quality deterioration with the onset of senescence (Pal and Roy, 1988). On the other hand, delay in the increment of TSS and reduction of acidity content of fruits stored in LDPE or PP with $KMnO_4$ treatment could be due to slow down of ripening as a result of apparent delay in the onset of elevated ethylene evolution in respiration (Jiang *et al.,* 1999). Moreover, active packaging may able to create such microenvironment inside the package with changed gaseous concentration that leads to result in marked reduction in rate of conversion of starch to sugars as compared to openly kept fruit control (Kudachikar *et al.,* 2011).

Reducing, Non-reducing and Total sugar content (%)

During postharvest ripening of banana, the most striking postharvest chemical changes occur is the hydrolysis of starch and accumulation of sugar i.e. sucrose, glucose and fructose which is responsible for the sweetness of the fruits (Palmer, 1971). The different treatments involved in this investigation were also found to be highly significant in relation to reducing, non-reducing and total sugar content [Fig. 1 (A-C)]. All the three types of sugar (total, reducing and non-reducing) showed a gradual increment over the advancement of storage period. Minimum time (9th day) to reach the peak of increment for total and reducing sugar executed by untreated fruits with a lowest value of 14.46% and 8.96%, respectively. Maximum time (24th day) to attain the peak value of both total and reducing sugar were required by T_2 (17.62% and 12.00%, respectively) and T_6 (16.50% and 11.50%, respectively). Similar trend of increment observed in non-reducing sugar also, but increment value was very less for all treatments as in case of untreated fruits, it was only 3.35% on day 3 to 5.50% on day 9. Highest value of non reducing sugar i.e. 5.66% obtained from banana treated with T_7 (on day 18) followed by T_2 (5.62% on day 24). Rapid increment in the total and reducing sugar contents of fruits stored in open air could be due to faster ripening process which converts starch into sugar, while the slower rate in the rest of the treatments could be due to the effects of the treatments in delaying the ripening process (Golding *et al.,* 2005). The more delay in increase of the sugars by inclusion of $KMnO_4$ in the polyethylene could be attributed to the ethylene removal effect of $KMnO_4$ (Jobling, 2000).

REFERENCES

Anon 2007. Scenario of banana production, utilization and trade. In: Proc National Conference on production and utilization of banana for economic livelihood and nutritional security, National Research Centre for Banana, Tiruchinapalli, India, 25-28th Oct. 2007, Organized by Association for Improvement in Production and Utilization of Banana, New Delhi, Indian Council of Agricultural Research, New Delhi.

Bhalerao, P. P., Parmar, B. R., Padhiar, B. V., Bhalerao, R. R. and Parmar, S. B. 2011. Effect of growth regulators on post-harvest life of banana cv. oicxitn NmNc. *Asian J. Hort.* **6:** 283-287.

Bhat, S. 2013. Minimal processing and preservation of fruits and vegetables by active packaging. *Int. J. Herbal Medicine.* **1:** 131-138.

Borkar, P. A., Jadhao, S. D., Bakane, P. H., Borkar, S. L. and Murumkar, R. P. 2008. Effect of ethylene absorbent and different packaging materials on storage life of banana. *Asian J. Bio Sci.* **3:** 233-236.

De Kruijf, N., Van Beest, M., Rijk, R., SipilainenMalm, T., Losada, P. P., De Meulenaer, B. 2002. Active and intelligent packaging: applications and regulatory aspects. *Food Additiv. Con.* **19:** 144- 162.

Dharmasenal, D. A. and Kumari, A. H. 2005. Suitability of charcoal-cement passive evaporative cooler for banana ripening. *J. Agri. Sci.* **1:** 1-10.

Dong, L., Lurie, S. and Zhou, H. W. 2002. Effect of 1-Methylcyclopropene on ripening of 'canino' apricots and 'Royal zee' plums. *Postharvest Biol. Tec.* **24:** 135-145.

Golding, J. B., Ekman, J. H. and McGlasson, W. B. 2005. Regulation of Fruit Ripening. Stewart Postharvest Review. *Postharvest Biol. Tec.* **3:** 1-5.

Jiang, Y., Joyce, D. C. and Macnish, A. J. 1999. Extension of the shelf life of banana fruit by 1-MCP in combination with polyethylene bags. *Postharvest Biol. Tec.* **16:**187-193.

Jobling, J. 2000. Postharvest ethylene a critical factor in quality management. *Sydney postharvest laboratory information sheet. Sydney, Australia.*

Khan, A. S., Malik, A. U., Pervez, M. A., Saleem, B. A., Rajwana, I. A., Shaheen, T. and Anwar, R. 2009. Foliar application of low-biuret urea and fruit canopy position in the tree influence the leaf nitrogen status and physico-chemical characteristics of Kinnow mandarin (*Citrus reticulata* Blanco). *Pakistan J. Bot.* **41:** 73-85.

Kotecha, P. M. and Babasaheb, B. D. 1995. Banana. In: D.K. Salunkhe and Kadam, S.S. (eds) *Fruit Sci. Tech.* pp. 67-90.

Kudachikar, V. B., Kulkarni, S. G. and Prakash, M. K. 2011. Effect of modified atmosphere packaging on quality and shelf life of 'Robusta'banana (*Musa sp.*) stored at low temperature. *J Food Sci. Tech.* **48:** 319-324.

Kudachikar, V. B., Kulkarni, S. G., Vasantha, M. S., Aravinda, P. B. and Aradhya, S. M. 2007. Effect of modified atmosphere packaging on shelf life and fruit quality of banana stored at low temperature. *J Food Sci. Tech.* **44:** 74-78.

Kumbargire, G. A., Swamy, G. S. K. and Kalatippi, S. A. 2016. Influence of diatomaceous earth as source of silicon on leaf nutrient status and yield attributing characters of banana cv. Grand Naine. *The Bioscan.***11(1):** 435-438.

Mandal, D., Lalrindika, E., Hazarika, T. K. and Nautiyal, B. P. 2016. Post harvest application of salicylic acid enhanced Shelf life and maintained quality of banana cv. 'Grand Naine' at ambient storage. *The Bioscan.* **11(1):** 265-270.

Mangaraj, S. and Goswami, T. K. 2009. Modified atmosphere packaging-Anideal food preservation technique. *J. Food Sci. Tech.* **46:** 399-410.

Mohapatra, D., Mishra, S. and Meda, V. 2009. Plantains and their postharvest uses: An overview. *Stewart Postharvest Review.* **5:** 1-11.

Mulagund, J., Kumar, S., Soorianathasundaram, K. and Porika, H. 2015. Influence of post-shooting sprays of sulphate of potash and certain growth regulators on bunch characters and fruit yield of banana cv. Nendran (French plantain Musa AAB). *The Bioscan.* **10(1):** 153-159.

NHB. 2015. Online statistical database of National Horticultural Board, Ministry of Agriculture, Govt. of India. http://www. Indiastat. com. (Accessed on February, 2015).

Pal, R. K. and Roy, S. K. 1988. Zero energy cool chambers for maintaining postharvest quality of carrot (*Daucus carota* var. *sativa*). *Indian J. Agri. Sci.* **58:** 665-667.

Patel, N. I. 2003. Effect of some chemicals and growth regulators on post harvest life of Banana cv. Grand Naine. *Thesis submitted to ASPEE College of Horticulture and Forestry, Navsari.*

Patil, S. N. and Hulmani, N. C. 1998. Effect of post-harvest treatments on the storage life of banana fruits. *Karnataka J. Agri. Res.* **11:** 134-138.

Salvador, A., Sanz, T. and Fiszman, S. M. 2006. Changes in colour texture and their relationship with eating quality during storage of two different dessert bananas. *Postharvest Biol. Tech.* **43:** 319-325.

Shashirekha, S., Scott, K. J. and Graham, D. 2007. Storage of banana in sealed polyethylene tubes. *CSIRO, Food Reaserch Laboratory, North Ryde Australia.*

Smith, N. J. S., Tucker, G. A. and Jeger, J. 1989. Softening and cell wall changes in bananas and plantains. *Aspects Applied Biol.* **20:** 57-65.

Thompson, A. K. 1998. Controlled atmosphere storage of fruits and vegetables. *CAB International,* New York

Waskar, D. P., Khedlar, R. M. and Garande, V. K. 1999. Effect of post harvest treatment on shelf life and quality of pomegranate in evaporative cooling chamber and ambient conditions. *J. Food Sci. Tech.* **2:** 114-117.

Zewter, A., Woldetsadik, K. and Workneh, T. S. 2012. Effect of 1-Methylcyclopropene, potassium permanganate and packaging on quality of banana. *African J. Agri. Res.* **7:** 2425-2437.