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Modified Atmosphere Packaging of Banana (cv. Pachbale) with Ethylene, Carbon di-oxide and Moisture Scrubbers and Effect on its Ripening Behaviour

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Abstract: The synergistic effect between modified atmosphere and potassium permanganate based ethylene scrubber on ripening behaviour of unripe banana fruits was evaluated at 13±1°C followed by ethrel induced ripening at 30±1°C. The type of modified atmospheres consisted of passive mode [prepackaged in polyethylene (PE) pouches] as well as active modes [gas flushed with 3% O_2 and 5% CO_2 in PE pouches and partial vacuum (400 mmHg) packaged]. The passive mode, gas flushing and vacuum packaging resulted in shelf-life extension to 15, 24 and 32 days, respectively as against shelf-life of 12 days for the experimental control. Application of ethylene scrubber in combination with silica gel as desiccant and soda-lime as CO_2 scrubber further enhanced the shelf-life to 18, 28 and 36 days under the different types of modified atmospheres specified. The synergistism was shown through ripening retardation characterized by late onset of respiratory climacteric, delayed degreening and restricted softening during ripening of banana.

Key words: Banana, modified atmosphere, ethylene scrubber, vacuum packaging, ripening, shelf life

Introduction

Banana is a major tropical fruit grown extensively in the tropics. The cultivar Pachbale is a major variety grown in Southern and Western India. However, despite the extensive work carried out on banana for the post harvest storage and transportation, certain problems have been reported by earlier workers which may potentially hinder the commercial utility of modified atmosphere storage of banana. Abdel-Rahman *et al.* (1995) reported excessive CO_2 accumulation and anaerobiosis during passive modified atmosphere storage in polyethylene films. Exposure of banana to nitrogen atmosphere alone has been found to cause off flavour development (Klieber *et al.*, 2002). Information is as such scarce on the remedial measures to address the limitations of polyethylene pouches for MAP storage of banana, being cost effective for field applications. The beneficial effect of ethylene scrubbing on the shelf-life of surface coated banana (cv. Robusta) in sealed packages has suggested a better utilization of ethylene scrubber in combination with MAP applications (Krishnamurthy and Khushalappa, 1985). Similarly, Chamara *et al.* (2000) reported the positive role of ethylene scrubber on banana (cv. Kolikuttu) stored under passive modified atmosphere under low temperature conditions. However, information is scarce with regards to restriction of CO_2 accumulation induced anaerobiosis and moisture condensation during passive as well as active generation of modified atmosphere using polyethylene films. Vacuum packaging of plantain bananas has been found to be useful for the preparation of fried banana slices. However, information is elusive with regard to the development of ethylene and CO_2 scrubbers with emphasis on integrated approach based on

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synergistic effects between scrubbers and modified atmosphere. The present study was aimed at development of low cost ethylene scrubber along with CO_2 absorbent and desiccants and to study the synergistic effects of passive as well as active modified atmosphere with scrubbers to enhance the shelf life and keeping quality of banana for storage under field conditions.

Materials and Methods

Fruits

Fully mature banana (cv. Pachbale), medium sized (90-100 g) at 3/4 full stage were procured from market as fully grown fronds and brought to Defence Food Research Laboratory, Mysore, India for the experiment. The fronds were cut in to hands, each having 10-12 fruits. All the bunches were green and labelled as stage 1 on the colour ripening chart. There was no visible transportation damage to the fruits.

Sanitation and Pretreatment

The fruits were washed with sanitized water followed by 200 ppm thiabendazole solution. The surface moisture was removed by placing the fruits in a stream of dehumidified air. Subsequently, the cut ends were sealed with waxol (2%) contained 0.2% potassium sorbate.

Packaging

The hands were packaged in polyethylene pouches (25 μ) as 1 kg units in three experimental blocks, as such, flushed with gas mixture and partial vacuum packaged along with CO_2 and moisture scrubbing agents. Gas flushing of the packages was carried out through vacuumization followed by gas flushing. A proportional gas mixer (PBI, Denmark) was used to obtain a specific gas mixture. Partial vacuum packaging was carried out by setting the vacuum at 400 mmHg. Another set of three experimental blocks were prepared for each specific type of packaging for incorporating ethylene, CO_2 and moisture scrubbing agents. The different types of modified atmospheres in combination with the scrubbing formulations were specified as follows; A: packaged in PE with CO_2 and moisture absorbents; B: packaged in PE with ethylene, CO_2 and moisture absorbents; C: gas flushed (3% O_2 and 5% CO_2) with CO_2 and moisture absorbents; D: gas flushed (3% O_2 and 5% CO_2) with ethylene, CO_2 and moisture absorbents; E: vacuum packaged (400 mmHg) with CO_2 and moisture absorbents and F: vacuum packaged (400 mmHg) with ethylene, CO_2 and moisture absorbents. The fruits were kept as such for control. All the samples were kept at 13±1°C for storage. The samples were shifted to 30±1°C after termination of storage; treated with 200 ppm ethrel and kept for ripening.

Ethylene, Carbon di-oxide and Moisture Absorbents

Ethylene scrubber in granulated form was prepared by impregnating potassium permanganate in an inert matrix consisting of white cement and limestone powder. The ethylene absorbing granules were packed in sachet form using HDPE woven fabric as 5 g units. Dry soda lime (3 g) and silica gel (2 g) were taken in porous cellulose based sachets. Each unit package of banana was incorporated with one sachet each of ethylene scrubber, CO_2 and moisture absorbent.

Experimental Set up

The resultant six experimental blocks consisted of ten 1 kg unit packages in each. The experiment was replicated thrice and sampling was carried out using a completely randomized block design. Results of each analysis have been reported as means of six replications.

Physico-chemical Analysis

Respiration and ethylene synthesis rates were monitored using gas chromatographic method described by Hakim *et al.* (2004) and Gailard and Grey (1969), respectively. Ascorbic acid content and titratable acidity were estimated by standard methods (AOAC, 1990), pH and soluble solids were measured by using pH meter (Century, Model CP 931, Century Instruments Private Limited, Chandigarh, India) and hand refractometer (Erma, Tokyo, Japan); respectively. The activity of polyphenol oxidase was estimated following the method of Bruske and Drapkin (1973).

Head Space Gas Analysis

Head space gas analysis of O_2 and CO_2 was carried out using O_2/CO_2 analyzer (PBI Dansensor, Checkmate 9900, Prg. Version 1.7, Denmark) having teflon septa and auto-injector.

Texture Analysis

Firmness of banana fruits was measured using a texture analyzer (TAHDi, Stable Microsystems, UK) equipped with a 5 kg load cell. The analyzer was linked to a computer that recorded data via a software programme called Texture Expert (Version 1.22, Stable Micro Systems, UK). Firmness evaluation was carried out by taking whole fruit with and without peel and penetrating it with a 2 mm diameter cylindrical rod at a speed of 0.5 mm sec^{-1} and automatic return. The downward distance was set at 10 mm and pre-test and post-test speeds were 1 and 10 mm sec^{-1}, respectively. Samples were positioned so that the rod penetrated their geometric centre at the middle of the fruit in longitudinal axis.

Colour

The tri-stimulus colour changes were recorded with D65 illuminating conditions at an observation interval of 2 nm. The instrument (Model 2810; Datalab India Pvt. Ltd., Silvasa, Gujrat, Inida) was calibrated using a standard ceramic white tile. The instrument was equipped with an inbuilt software (Chromaflash) to denote L as well as a and b values. The L, a, b values were taken in the hunter scale.

Sensory Evaluation

The sensory attributes of ripened fruits in each experimental block were evaluated in terms of colour, aroma, taste, texture and overall acceptability by a panel consisting of 10 members using a nine point hedonic scale showing a score of 9 for extreme liking and 1 for extreme disliking (Larmond, 1977).

Statistical Analysis

The data obtained from physico-chemical analysis and sensory evaluation were analyzed statistically for analysis of variance (ANOVA) using completely randomized design with Least Significant Difference (LSD) at $p<0.05$ using Statistica 7 software (StatSoft, Tulsa, OK, USA).

Results and Discussion

Respiration

The respiratory pattern (Fig. 1) showed varied physiological response of the fruits towards the modified atmosphere. The respiration of banana as such followed a climacteric pattern. The different modified atmospheres applied, showed a significant ($p\leq 0.01$) effect on the respiration in terms of magnitude as well as the extent of pre-climacteric phase vis-à-vis the control samples. A progressive increase in the pre-climacteric phase was recorded for polyethylene packaged (passive MAP) samples followed by gas flushed and vacuum packaged ones. The retardatory effect of MAP can be attributed to the low O_2 tension mediated restriction of synthesis of key enzymes and metabolites responsible

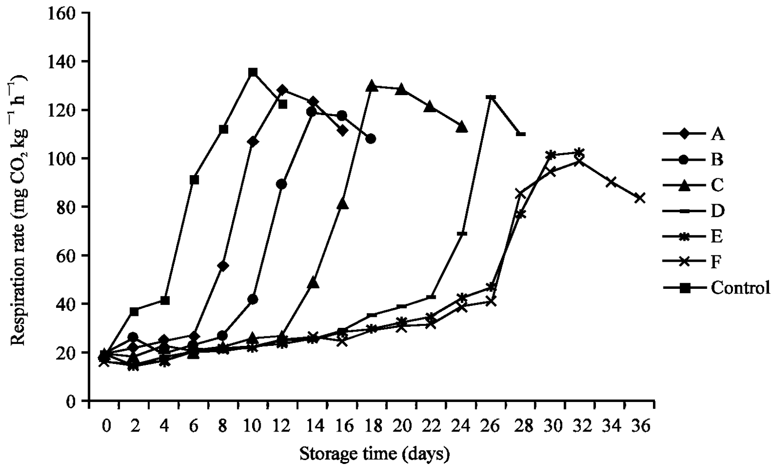

Fig. 1: Respiration profile of modified atmosphere packaged banana during storage at low temperature (13±1°C) and etherel induced ripening (30±1°C). A: PE packaged with CO_2 and moisture absorbents; B: PE Packaged with ethylene, CO_2 and moisture absorbents; C: Gas flushed with CO_2 and moisture absorbents; D: Gas flushed with ethylene, CO_2 and moisture absorbents; E: Vacuum packaged with CO_2 and moisture absorbents and F: Vacuum packaged with ethylene, CO_2 and moisture absorbents

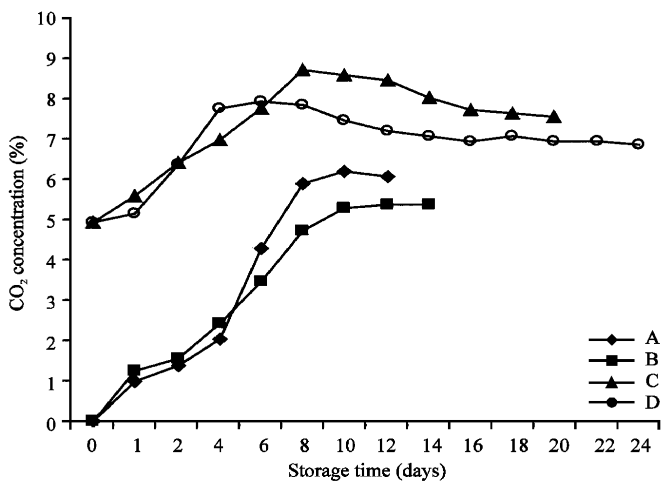

Fig. 2: Changes in head space CO_2 concentration during storage of modified atmosphere packaged banana at low temperature (13±1°C). A: PE packaged with CO_2 and moisture absorbents; B: PE Packaged with ethylene, CO_2 and moisture absorbents; C: Gas flushed with CO_2 and moisture absorbents and D: Gas flushed with ethylene, CO_2 and moisture absorbents

for ripening (Goodenough *et al.*, 1982). The synergistic effect of ethylene absorbent also resulted in a decrease in respiratory magnitude and a corresponding increase in the duration of pre-climacteric respiration. Partial vacuum packaging caused a drastic fall in the magnitude of climacteric respiration

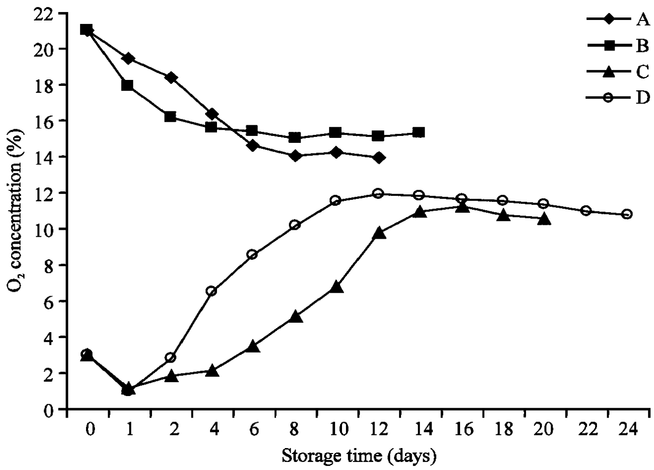

Fig. 3: Changes in head space O_2 concentration during storage of modified atmosphere packaged banana at low temperature (13±1°C). A: PE packaged with CO_2 and moisture absorbents; B: PE Packaged with ethylene, CO_2 and moisture absorbents; C: Gas flushed with CO_2 and moisture absorbents and D: Gas flushed with ethylene, CO_2 and moisture absorbents

vis-à-vis fruits stored in other types of modified atmospheres as well as that of experimental control samples. Beneficial effect of modified atmosphere on the shelf-life of banana (cv. Cavendish) has been reported earlier (Choehom *et al.*, 2004) with simultaneous restriction of texture loss and degreening. However, excessive accumulation of CO_2 is a major problem when polyethylene films are used for the passive generation of modified atmosphere. Abdel-Rahman *et al.* (1995) have reported excessive accumulation of CO_2 when bananas were packaged in 100 gauge polyethylene films. Despite the retarded respiration mediated by passive as well as active modes of modified atmosphere packaging, the sub-optimal barrier properties of polyethylene can be a hindrance for MAP storage of fresh produce such as banana.

Head Space Gas Analysis

The inclusion of CO_2 scrubber in the form of soda lime in the study could restrict the head space CO_2 concentration below 7% (Fig. 2) otherwise CO_2 levels were found to be more than 9-10% with appearance of anaerobic symptoms and off flavour development. Symptoms of cytotoxicity were also observed under excessive accumulation of CO_2. The head space O_2 concentration (Fig. 3) showed lower equilibriated O_2 concentration in the case of gas flushed samples (10-12%) vis-à-vis those stored under passive generation (14-16%). The fill weight, fill volume and storage temperatures played an important role in arriving at optimal equilibriated O_2 and CO_2 concentrations. The results obtained in terms of head space gas composition are specific to the optimized MAP variables described. In addition to MAP variables, the barrier properties of polyethylene are also crucial and PE as such does not possess enough CO_2 permeation. However, the inclusion of CO_2 scrubber was found beneficial in avoiding excessive CO_2 accumulation in the head space, thereby, enhancing the sensory perception of stored bananas. The vacuum packaged samples developed detectable head space gases after 3 weeks of storage under low temperature conditions with relatively lower O_2 (2-4%) and CO_2 (4-6%) concentrations. The net extension in shelf life can be attributed to the overall low O_2 tension that prevailed throughout

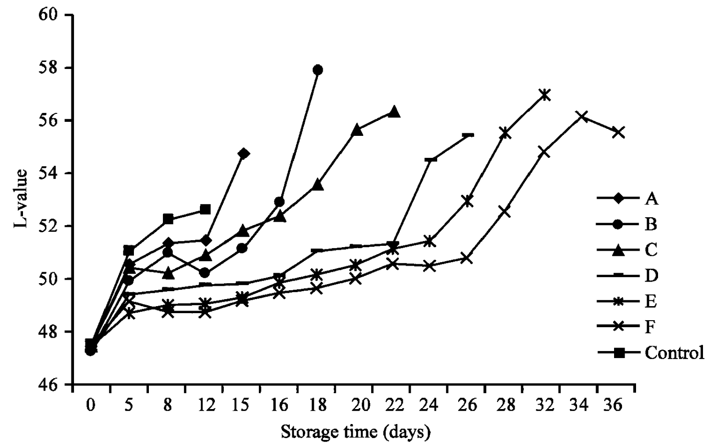

Fig. 4: Changes in L-value during modified atmosphere storage of banana at low temperature (13±1°C) and etherel induced ripening (30±1°C). A: PE packaged with CO_2 and moisture absorbents; B: PE Packaged with ethylene, CO_2 and moisture absorbents; C: Gas flushed with CO_2 and moisture absorbents; D: Gas flushed with ethylene, CO_2 and moisture absorbents; E: Vacuum packaged with CO_2 and moisture absorbents and F: Vacuum packaged with ethylene, CO_2 and moisture absorbents

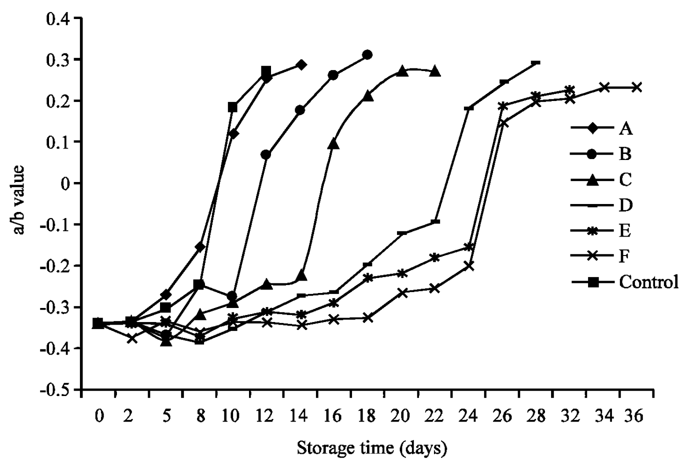

Fig. 5: Changes in a/b value during modifed atmosphere storage of banana at low temperature (13±1°C) and etherel induced ripening (30±1°C). A: PE packaged with CO_2 and moisture absorbents; B: PE Packaged with ethylene, CO_2 and moisture absorbents; C: Gas flushed with CO_2 and moisture absorbents; D: Gas flushed with ethylene, CO_2 and moisture absorbents; E: Vacuum packaged with CO_2 and moisture absorbents and F: Vacuum packaged with ethylene, CO_2 and moisture absorbents

the storage of partially vacuum packed samples. The synergistic effect between ethylene absorbent and MAP resulted in a restricted CO_2 accumulation as compared to MAP samples stored without ethylene absorbent.

Colour

The tri-stimulus colour profile of MAP stored banana with and without ethylene absorbent showed a colour profile in compliance with differential colour break durations mediated by the different modes of MAP. As such a steady increase in L-value was observed followed by sharper increment upon shifting of samples for ethrel induced ripening at 30°C. All the three types of MAP samples i.e. passive, gas flushed and partially vacuum packaged showed a significant ($p \leq 0.01$) variation vis-à-vis control samples in terms of L-values (Fig. 4) and a/b values (Fig. 5). However, in the case of L-values the variation among passive packaging with ethylene absorbent and without ethylene absorbent as well as partially vacuum packed samples was found to be significant ($p \leq 0.05$). No significant difference was observed on application of ethylene absorbent in use of the gas flushed samples in terms of L-values. As far as a/b values are concerned, all the three types of MAP with and without ethylene absorbent had a significant ($p \leq 0.01$) effect. The results show a consistent effect of modified atmospheres depicting a delayed colour break and degreening process characterized by a progressive increment in the lightness and less green and more yellow nature, especially at the stage of ethrel induced ripening at 30±1°C.

PPO Activity

The polyphenol oxidase activity increased during the ripening of banana stored with and without application of MAP. The initial activity was found to be 104.3 units g^{-1} (fr. wt.) and on the day of shifting control to ethrel induced ripening conditions at 30±1°C, the different types of MAP with and without ethylene absorbent showed A-549.8, B-517.7, C-436.4, D-335.4, E-230.1 and F-218.9 units g^{-1} (fr. wt.) vis-à-vis the control (552.6 units g^{-1} on fr. wt.). All the three types of modified atmospheres along with the use of ethylene absorbent showed significant ($p \leq 0.01$) variation among them as well as from control showing the retardatory effect of modified atmosphere on PPO activity. Earlier, Thuy-Nguyan *et al*. (2004) reported a restricted activity of phenylalanine lyase and PPO of banana after the application of 12% O_2 and 4% CO_2 at 10°C. It is also known that rise in PPO has a positive correlation not only with browning potential but also with other enzymes such as catalase and acid phosphatase (Sharon and Kahn, 1979). The present study indicated the retardatory effects of modified atmosphere with PPO as enzymatic marker for the advancement of ripening/senescence and the same could be attributed to the delayed senescence under low oxygen atmosphere.

Firmness

Bananas are highly susceptible for softening during ripening and it is essential to restrict softening through suitable post harvest handling techniques. Several reports exist regarding the changes in the textural profile during ripening of banana (Peleg and Britto, 1977). Chen and Ramaswamy (2002) described kinetics of textural changes during banana ripening. Chemical regulation of banana ripening essentially involves pretreatments including infusion of calcium ions to restrict the solubilization of pectinaceous materials (Perera and Karunaratne, 2002). However, the literature on changes in textural characteristics with respect to modified atmosphere applications as scanty. Changes in firmness values with and without peel suggested that all the three types of modified atmospheres could restrict softening significantly ($p \leq 0.01$) (Table 1) vis-a-vis control samples. As on the day of shifting of control for ethrel induced ripening at 30±1°C (8th day), all the three types of modified atmospheres with and without ethylene absorbent showed significant ($p \leq 0.01$) restriction in softening compared to than in control. However, passive packaging in PE without ethylene absorbent showed less significant ($p \leq 0.05$) variation. In case of firmness values of banana without peel, stored in vacuum pack, showed higher firmness vis-à-vis those stored under gas flushed conditions, passive packaging and control. Observations suggested that there was toughening of tissue which might have impeded

Table 1: Changes in firmness of modified atmosphere packaged banana during storage (n = 6)

	Firmness whole (g)		Firmness without Peel (g)	
Treatment	Control shifting day (8th day)[1]	Final individual termination day[2]	Control shifting day (8th day)[1]	Final individual termination day[2]
Initial	1437.38		454.90	
A	361.58	367.85	45.28	40.93
B	397.65	374.74	46.88	36.67
C	1325.21	454.23	332.99	52.70
D	1361.28	487.51	401.61	51.55
E	1335.36	512.34	441.90	60.70
F	1355.00	561.23	446.52	78.74
Control	352.66	332.66	44.21	34.21
CD ($p \leq 0.05$)	17.460	8.052	9.547	1.997
SEM±	5.757	2.655	3.147	0.658

A: PE packaged with CO_2 and moisture absorbents; B: PE Packaged with ethylene, CO_2 and moisture absorbents; C: Gas flushed with CO_2 and moisture absorbents; D: Gas flushed with ethylene, CO_2 and moisture absorbents; E: Vacuum packaged with CO_2 and moisture absorbents and F: Vacuum packaged with ethylene, CO_2 and moisture absorbents. [1]Day of shifting of control samples from 13±1 to 30±1°C for ethrel induced ripening. [2]Shelf life of different individual blocks is given in Table 4

Table 2: Changes in ascorbic acid content and pH of modified atmosphere packaged banana during storage (n = 6)

	Ascorbic Acid (mg/100 g)		pH	
Treatment	Control shifting day (8th day)[1]	Final individual termination day[2]	Control shifting day (8th day)[1]	Final individual termination day[2]
Initial	14.30		4.36	
A	10.70	7.01	4.52	5.09
B	11.75	7.20	4.50	5.10
C	10.80	7.18	4.45	5.12
D	11.90	7.26	4.42	5.10
E	11.15	8.60	4.40	5.02
F	12.20	9.82	4.38	5.04
Control	8.37	5.70	4.98	5.12
CD ($p \leq 0.05$)	0.173	0.084	0.097	0.037
SEM±	0.057	0.028	0.032	0.012

A: PE packaged with CO_2 and moisture absorbents; B: PE Packaged with ethylene, CO_2 and moisture absorbents; C: Gas flushed with CO_2 and moisture absorbents; D: Gas flushed with ethylene, CO_2 and moisture absorbents; E: Vacuum packaged with CO_2 and moisture absorbents and F: Vacuum packaged with ethylene, CO_2 and moisture absorbents. [1]Day of shifting of control samples from 13±1 to 30±1°C for ethrel induced ripening. [2]Shelf life of different individual blocks is given in Table 4

normal ripening and sensory attributes under prolonged storage on vacuum pack storage. The persistence of firmness may be attributed to partially vacuumized nature of the head space as well as the presence of low oxygen atmosphere. Therefore, it was essential to shift the vacuum packaged samples from the low temperature storage to ripening temperature (30±1°C) for obtaining optimal texture upon ripening. Few reports exist regarding the application of vacuum packaging for the storage of banana. Bacetti and Falcone (1995) described a shelf life of 8 weeks for the Cavendish variety of banana at 6-7°C. However, the toughening of tissue was not mentioned which needed further study. In the present study termination of low temperature storage for partially vacuumized samples insured that there were no symptoms of anaerobiosis in the bananas and subsequent ethrel induced ripening did not show any abnormal trend which could impede the sensory properties. The application of ethylene absorbent in combination with MAP was helpful in restricting the softening of the fruits.

Physico-chemical Changes

The three types of modified atmospheres showed a significant ($p \leq 0.01$) restriction in ascorbic acid losses compared to that in control. The ripening process of fruits is usually associated with

Table 3: Changes in Pulp: Peel and Brix: Acid ratio of modified atmosphere packaged banana during storage (n = 6)

	Pulp: Peel		Brix: Acid	
Treatment	Control shifting day (8th day)[1]	Final individual termination day[2]	Control shifting day (8th day)[1]	Final individual termination day[2]
initial	1.39		25.97	
A	1.86	2.31	68.63	116.28
B	1.70	2.20	65.16	122.33
C	1.60	2.63	34.82	136.84
D	1.54	2.75	33.41	125.24
E	1.46	2.22	28.13	100.02
F	1.41	2.15	27.70	98.26
Control	2.23	2.63	106.92	126.92
CD ($p \leq 0.05$)	0.053	0.048	2.397	1.623
SEM±	0.017	0.016	0.790	0.535

A: PE packaged with CO_2 and moisture absorbents; B: PE Packaged with ethylene, CO_2 and moisture absorbents; C: Gas flushed with CO_2 and moisture absorbents; D: Gas flushed with ethylene, CO_2 and moisture absorbents; E: Vacuum packaged with CO_2 and moisture absorbents and F: Vacuum packaged with ethylene, CO_2 and moisture absorbents. [1]Day of shifting of control samples from 13±1 to 30±1°C for ethrel induced ripening. [2]Shelf life of different individual blocks is given in Table 4

Table 4: Shelf life of modified atmosphere packaged banana fruits in PE pouches upon low temperature storage (13±1°C) followed by ethereal induced ripening (30±1°C)

Treatment	Day of shifting to 30° C	Total shelf Life (days)
A	13	15
B	15	18
C	21	24
D	25	28
E	28	32
F	30	36
Control	8	12

A: PE packaged with CO_2 and moisture absorbents; B: PE Packaged with ethylene, CO_2 and moisture absorbents; C: Gas flushed with CO_2 and moisture absorbents; D: Gas flushed with ethylene, CO_2 and moisture absorbents; E: Vacuum packaged with CO_2 and moisture absorbents and F: Vacuum packaged with ethylene, CO_2 and moisture absorbents

gradual or rapid depletion of ascorbic acid (Rouse and Aulin, 1977). However, the effect of modified atmosphere on ascorbic acid retention has received scanty attention and the present study (Table 2) showed that the modified atmospheres applied with and without ethylene absorbent could restrict ascorbic acid loss highly significantly ($p \leq 0.01$). The use of ethylene absorbent did not show any significant effect on the retention of ascorbic acid vis-à-vis absence the same.

The pH shift during ripening between the MAP stored samples and control was highly significant ($p \leq 0.01$). Application of ethylene absorbent did not show any significant variation when coupled with modified atmosphere.

Pulp to peel and brix to acid ratio showed a steady increase during the low temperature storage followed by a sharp increment upon ethrel induced ripening at 30±1°C (Table 3). The MAP stored samples showed significant ($p \leq 0.01$) variation vis-à-vis control samples both in the case of pulp to peel and brix to acid ratios. However, the use of ethylene absorbent was found to restrict rise in pulp/peel and brix/acid ratios significantly only in the case of passive modified atmosphere. These trends showed a conspicuous retardation in ripening by the application of modified atmospheres. All the MAP stored samples showed normal attainment of brix/acid ratio vis-à-vis control samples. However, the vacuum packaged samples showed significantly ($p \leq 0.01$) lower attainment of brix/acid ratio while the further storage of vacuum packaged sample at low temperature was found to impede the attainment of normal brix/acid ratio lowering the sensory perception of ripening.

Table 5: Sensory scores for modified atmosphere packaged banana at the end of shelf life after ethereal induced ripening at 30±1°C (n = 6)

Treatment	Colour	Aroma	Taste	Texture	Overall acceptability
A	8.00	7.75	7.47	7.50	7.20
B	8.08	7.92	7.52	7.51	7.25
C	7.89	7.75	7.63	7.65	7.56
D	7.97	7.75	7.85	7.58	7.60
E	7.50	7.70	7.23	7.12	7.12
F	7.48	7.13	7.15	7.05	7.10
Control	7.50	7.50	7.35	7.60	7.25
CD ($p \leq 0.05$)	0.578 ns	0.161	0.067	0.107	0.131
SEM±	0.191	0.053	0.022	0.035	0.043

A: PE packaged with CO_2 and moisture absorbents; B: PE Packaged with ethylene, CO_2 and moisture absorbents; C: Gas flushed with CO_2 and moisture absorbents; D: Gas flushed with ethylene, CO_2 and moisture absorbents; E: Vacuum packaged with CO_2 and moisture absorbents and F: Vacuum packaged with ethylene, CO_2 and moisture absorbents

Sensory Evaluation and Shelf Life

The three types of modified atmospheres resulted in an extension in shelf life of banana unripe (cv. Pachbale) to varying extent. Modified atmospheres with CO_2 scrubber and moisture traps alone could extend the shelf life to 15, 24 and 32 days in case of the passive (packaged in PE), gas mixture flushed and partially vacuum packed samples, respectively (Table 4). The use of ethylene absorbent could further extend the shelf life to 18, 28 and 36 days in case of all the three modified atmospheres respectively. The visual symptoms of microbial spoilage were absent. Earlier reports have suggested to restrict propagation of *in vivo* inoculated fungal cultures in response to modified atmosphere with low O_2 and high CO_2 conditions (Wade *et al*., 1993). Apart from being free from fungal infection, all the modified atmosphere stored samples showed consistent sensory scores of above 7 on a nine point hedonic scale upon ethrel induced ripening (Table 5). Several earlier workers have stressed the importance of peel spotting during the modified atmosphere storage of banana and the restriction of the same may be attributed either to, the low levels of O_2 (Choehom *et al*., 2004) or the cytotoxic effects of excessive accumulation of CO_2 (Satyam *et al*., 1992). Satisfactory colour quality was obtained, may be attributed to, the maintenance of CO_2 scrubber to restrict accumulation of excessive CO_2 and the regulation of moisture condensation within the package by replacement of moisture traps thereby decreasing microbial infection induced peel discolouration.

Conclusions

Modified atmosphere with passive and active modes could extend the shelf life of banana to 18-36 days. The active modes include flushing of pouches with gas mixture (3% O_2 and 5% CO_2) giving a shelf life of 28 days, vacuum packaging 36 days under low temperature storage at 13±1°C followed by ethrel induced ripening at 30°C. The study also showed that the synergistic effects of the developed ethylene and CO_2 scrubbers could restrict the accumulation of excessive CO_2 within the pouches lowering the cytotoxicity and symptoms of anaerobiosis in the ripened banana. Standardization of threshold duration for low temperature storage of vacuum packaged banana could maximize the beneficial effects without impeding the sensory quality. The variety of banana evaluated (cv. Pachbale) is extensively grown in India and application of developed low cost scrubbers along with modified atmosphere could possibly facilitate transportation and marketing of the same for domestic as well as for export markets.

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