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EXTENSION OF STORAGE LIFE OF 'KOLIKUTTU' BANANAS

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ABSTRACT

Green, mature Kolikuttu banana were stored in modified atmosphere at 10 °C, 15 °C, and ambient temperature (25-28 °C) in order to extend the storage life during export by sea. The modified atmospheres were created by enclosing bananas in polyethylene bags and evacuating the excess gas in the bag before sealing. Control fruits were stored in perforated polyethylene bags at each temperature. All modified atmosphere stored fruit at 15 °C remain green and firm until 30 days of storage indicating that the ripening process had not been initiated. When the stored fruits were taken out and induced for ripening, the process occurred normally and the eating quality remained at a highly acceptable level. Modified atmosphere did not impair the ripening process and eating quality of stored bananas. Although fruits stored at 10 °C remain firm for 30 days, excessive chilling injury to the peel cause extremely poor external appearance. However, modified atmosphere was effective in alleviating chilling damage for up to 10 days at 10 °C. Modified atmosphere was not effective extending the storage life at ambient temperature.

KEY WORDS: Chilling injury, Low temperature storage, Modified atmosphere, storage Life, Banana

INTRODUCTION

Banana is an important food commodity and the world annual production is nearly 700 million MT of which only 10 % of the production enters the international trade. Mainly the Cavendish type bananas enter the international markets, while the non export varieties are of diverse genotypes (Ploetz et al., 1994). Chandrarathna and Nanayakara (1951) has reported that 29 cultivated banana varieties are available in Sri Lanka of which some may be of value in the export market.

"Kolikuttu" is a high flavored type of banana, which belongs to the group AAB (Stover and Simmonds, 1987). This type is cultivated mainly in the dry and intermediate zones of Sri Lanka. Early ripening after harvest of this type of banana is an inherent character which shortens the storage life or green life compared to Cavendish type. At present, a small volume of Kolikuttu bananas are exported by air and this volume cannot be expanded due to limited cargo space and high cost involved. If the storage life is extended the volumes of export can be increased by sea freight.

Storage life of perishables can be extended by reducing the rate of respiration. This can be achieved by lowering the storage temperature or modifying the gaseous environment around the fruit. Favorable modification can be achieved by lowering oxygen and increasing carbon dioxide concentrations. One way of achieving a modified atmosphere is by sealing bananas in low density polyethylene bags where the gas composition gets modified through the process of respiration. This low cost technique can be adopted in Sri Lanka. Use of modified atmosphere to increase the storage life of Cavendish bananas and Embul bananas have been reported by Scott et al. (1971) and Sarananda (1989) respectively. This paper describes the results of experiments carried out to extend the storage life of Kolikuttu bananas by modified atmosphere.

MATERIALS AND METHODS

Freshly harvested mature, green 'Kolikuttu' bananas obtained from Chilaw were used for the experiment. Bunches were carefully transported to the laboratory on the same day. After dehanding, the hands were cut into 3 clusters, washed with running tap water and air dried.

Three clusters each containing five to six fruits were randomly selected and enclosed in low density polyethylene bags (10 X 12 cm) of 0.05 mm thickness and sealed to create a modified atmosphere. Similarly another set of bags were evacuated by using the inlet tube of a pump to remove excess gas in the package, thus modifying atmosphere by vacuum packing. The control fruits were packed

in similar sized bags, containing 16 perforations (diameter of 1 cm). Nine packs from each treatment were stored at temperatures of 10 °C, 15 °C and ambient (25-28 °C). Sampling was done at 10 day intervals. Three bags from each treatment were analyzed for their quality. The quality parameters tested were peel color, presence of chilling injury, total soluble solids and titrable acidity. The percentage weight loss was also recorded.

The fruits from each treatment were induced for ripening by exposing to acetylene liberated from calcium carbide (1 g/kg of banana). At the table ripe stage, the total soluble solids (TSS) was determined using a refractometer and titrable acidity (TA) was quantified by titrating against 0.1 N NaOH using phenolphthalein as an indicator. The peel color was monitored using a 1-7 index; i.e., 1=green and 7= yellow with brown flecks. Chilling injury was recorded visually by using 0-3 index; i.e., 0= no injury and 3=high chilling injury. The flesh color, aroma, smoothness and sweetness of the flesh of ripened banana was evaluated on a seven point hedonic scale using 10 member trained taste panel

Data on percentage weight loss, flesh firmness, total soluble solids and titratable acidity were statistically analyzed using ANOVA in two factor factorial design with 3 replications. Non parametric data recorded on flesh color, aroma, smoothness and sweetness were analyzed using Kruscal Wallis test.

RESULTS AND DISCUSSION

Peel color development

Peel color of bananas recorded at 10, 20 and 30 days of storage at 10 °C, 15 °C and ambient temperature is shown in Table 1. No changes in the peel color was observed in fruits stored in sealed and vacuum sealed MA even at 30 days of storage at 10 °C and 15 °C. However, fruits stored in sealed polyethylene bags at ambient temperature showed changes in the peel color indicating that ripening process has been initiated. Control fruits, which were stored in perforated polyethylene bags for 10 days, fully ripened at ambient temperature. All the treatments stored at 10 °C remained green up to

30 days. However, control fruits stored at 15 °C ripened at 20 days of storage.

Table 1. Mean peel color development of 'Kolikuttu' bananas stored at 10 °C and 15 °C.

Packaging	Peel color index for storage days						
	10			20		30	
	10 °C	15 °C	Ambient	10 °C	15 °C	10 °C	15 °C
SPEB	1	1	5	1	1	1	1
EPEB	1	1	1	1	1	1	1
Cont	1	1	7	1	5	1	7

Each data point represents a mean of three samples. Peel color index: 1= green, 2=color break, 3= more green than yellow, 4= more yellow than green, 5= yellow with green tip, 6= full yellow and 7= yellow with brown flecks. SPEB= sealed polyethylene bag, EPEB= evacuated polyethylene bag. Control= polyethylene bags with perforations.

Unchanged green color in all MA stored fruits at 10 °C and 15 °C was an indication that ripening process has not been initiated. Even though fruits in evacuated polyethylene bags stored at ambient did not ripened after 10 days, those fruits ripened after 20 days of storage. The absence of peel color development in control fruits stored at 10 °C showed that low temperature alone delayed the ripening process.

Chilling Injury

Visual assessment of chilling injury of bananas is given in Table 2. No chilling injury was observed in all bananas stored at 15 °C throughout the storage period. However, a moderate chilling damage was noticed in fruits stored in sealed polyethylene bags at 10 °C for 20 days of storage and thereafter. Although no chilling injury was noted in bananas stored in evacuated polyethylene bags at10 °C for 20 days, the injury was very high after 30 days of storage.

Table 2. Visual assessment of chilling injury of Kolikuttu bananas stored at 10 °C and 15 °C, for 10, 20 and 30 days.

Packaging	Chilling Injury on storage for days					
	10		20		30	
	10 °C	15 °C	10 °C	15 °C	10 °C	15 °C
SPEB	0	0	2	0	3	0
EPEB	0	0	0	0	3	0
Cont	1	0	3	0	3	0

Each value represents mean of 3 samples. SPEB= sealed polyethylene bag, EPEB= evacuated polyethylene bag. Chilling injury scale: 0= no chilling injury, 1= low upto 10% surface brown, 2= moderate injury 11-30% surface brown , 3= high more than 30% surface brown.

Chilling injury is a physiological change of the tissue to low temperature below the critical points, this injury can be seen as brown patches on the skin and later convert to dark brown or black patches (Lyons, 1973). Modified atmosphere has been reported to alleviate chilling injury in avocado (Scott, 1978). Similarly,

bananas may also be stored at 10 °C for a reasonable time. Delay in chilling injury in sealed polyethylene bags and evacuated polyethylene bags stored bananas compared to control may be due to the effect of modified atmosphere. However, manifestation of visible chilling injury after 20 days in seal polyethylene bags and evacuated polyethylene bags stored bananas, shows that the alleviating property of the modified atmosphere is not effective in the present case.

Percentage weight loss

.No significant interaction was observed between storage temperature and packaging used for the study. The percentage weight loss among all treatments after 10 days of storage was not significantly different. (Table 3). However, the highest weight loss was observed in control fruits stored in 15 °C for 20 days. All modified atmosphere stored fruits showed the minimum weight loss regardless of the storage temperature after 20 days of storage. The weight loss of control fruit was high at 30 days of storage.

Table 3. Percentage weight loss (square root transformation) of 'Kolikuttu' bananas stored at 10 °C and 15 °C for 10, 20 and 30 days.

Treatment		% weight loss on storage for days		
		10	20	30
10 °C	SPEB	1.17	1.15c	1.68c
	EPEB	1.06	1.05c	1.09e
	Control	1.09	2.02b	3.15a
15 °C	SPEB	1.13	1.26c	1.62cd
	EPEB	1.05	1.21c	1.38d
	Control	2.11	2.68a	2.03b
Ambient °T	SPEB	1.34	-	-
	EPEB	1.06	-	-
	Control	1.98	-	-
CV%		8.13	8.97	8.63

Each data point represents mean of 3 samples. SPEB= Sealed polyethylene bag, EPEB= evacuated polyethylene bag, Treatment means having a similar letter in the same column shows no significant difference by DMRT 5%.

Weight loss of Banana is mainly due to moisture loss through transpiration. When bananas are stored in modified atmosphere the humid environment develop in the sealed polyethylene bags bring down the water pressure deficit to a minimum resulting in a very low moisture loss. Although low temperature reduces the rate of biological reaction, less humid environment in perforated polyethylene bags would have caused a high moisture loss.

Flesh firmness

Flesh firmness of banana showed no significant interaction between storage temperature and packaging used for the study. The lowest flesh firmness was observed in all fruit stored at ambient temperature at 10 days (Table 4). Similarly the lowest flesh firmness was recorded in control fruits stored at 15 °C at 20 and 30 days. When modified atmosphere stored bananas at 15 °C were induced to ripen, no differences in the firmness was observed in all fruits at all storage periods. However, when bananas stored at 10 °C were ripened the flesh firmness was higher than that of at 15 °C. The minimum flesh firmness was recorded in control fruits stored at 15 °C for 30 days.

Flesh firmness is reduced when ripening process is initiated. Result shows that modified atmosphere was not effective in maintaining the flesh firmness of Kolikuttu bananas stored at ambient temperature for over 10 days. However, the modified atmosphere was effective when the fruits were stored at both 10 °C and 15 °C.

Table 4. Flesh firmness of 'Kolikuttu' bananas stored at 10 °C and 15 °C for 10, 20 and 30 days.

Treatment	Firmness kg/ cm					
	Storage time			After inducing ripening		
	10 days	20 days	30 days	10 days	20 days	30 days
10 °C						
SPEB	1.84cd	2.13b	2.01b	0.81a	0.98a	1.42a
EPEB	1.56de	2.37a	2.28ab	0.79a	1.00a	1.52a
Cont	2.95a	2.13bb	2.56a	0.76a	1.19a	1.60a
15 °C						
SPEB	2.25bc	2.07b	2.34ab	0.49b	0.49b	0.49b
EPEB	2.59ab	2.37a	2.37ab	0.49b	0.49b	0.49b
Cont	1.63de	0.49c	0.49c	0.49b	0.49b	0.49b
Amb						
SPEB	0.49f	-	-	0.49	-	-
EPEB	1.39e	-	-	0.49	-	-
Cont	0.49f	-	-	0.49	-	-
Sig.	*	*	*	*	*	*
CV(%)	8.56	6.92	10.21	18.36	30.21	11.21

Each data point represents mean of 3 samples. SPEB= sealed polyethylene bag, EPEB= evacuated polyethylene bag, Trt = treatment, Cont = control, ambient, *= $p<0.05$ significant. Treatment means having a similar letter in the same column shows no significant difference by DMRT 5%.

Control fruits stored at 15 °C for 12 days lost flesh firmness. However, when MA stored fruit were induced for ripening after 10-12 days, no differences were observed in firmness. This indicated that the ripening process of these fruits has not been impaired by storing in modified atmosphere. Flesh firmness of the ripened fruits stored in modified atmosphere for 30 days shows that ripening

process was uniform regardless of the modified atmosphere package and the storage temperature. The relatively higher flesh firmness of the ripened fruits stored at 10 °C may be due to effect of chilling.

Total Soluble Solids

No significant difference in interaction was found between storage temperature and packaging used for the experiment. The highest total soluble solids (TSS-indicated by Brix value) were observed in the control fruits stored at ambient temperature for 10 days (Table 5). Similarly the brix values were higher in control fruits stored at 15 °C for 20 and 30 days. When the MA stored fruits were ripened the amount of total soluble solids remains similar to that of control. On the other hand fruits stored at 10 °C for 20 and 30 days showed lesser soluble solids when they were ripened.

Increase in total soluble solids is a strong indication of initiation of the ripening process. Control fruits as well as sealed polyethylene bags stored fruits at ambient temperature soften as early as 10 days of storage. Control fruits stored at 15 °C showed increase value of TSS at each sampling time indicating that ripening process has been initiated. However, no change TSS values were observed in all modified stored fruits at 10 and 15 °C. When modified atmosphere stored fruits were induced for ripening softening process has progress similar to control fruits indicating that modified atmosphere has not affected the softening process.

Titrable Acidity

Interaction between the storage temperature and the packaging used to store was found to be not significant. The titrable acidity of control and sealed polyethylene bags stored bananas at ambient temperature for 10 days increased considerably (Table 6). The titrable acidity of all modified atmosphere stored fruits at 10 °C and 15 °C for 20 and 30 days remained at very low level. When modified

atmosphere stored fruits were ripened the titrable acidity values were comparable to that of control fruits, at table ripe stage.

Table 5. Total soluble solids of 'Kolikuttu bananas stored at 10 °C and 15 °C for 10, 20 and 30 days

Treatment	Total soluble solids (Brix)					
	Storage time			After inducing ripening		
	10 days	20 days	30 days	10 days	20 days	30 days
10 °C						
SPEB	4.53cd	4.00b	4.88	20.52	18.83b	18.49b
EPEB	4.00	4.04	5.66	2088	18.49b	18.66b
Cont	2.95e	3.45bc	3.84d	21.52	19.18b	18.83b
15 °C						
SPEB	2.92e	2.95c	2.99d	21.52	22.09a	22.18a
EPEB	2.89e	2.89c	2.89d	20.79	22.46a	22.46a
Cont	5.15c	2043a	21.52a	21.52	20.52a	20.52a
Amb						
SPEB	3.20b	-	-	20.91	-	-
EPEB	2.99e	-	-	20.83	-	-
Cont	21.71a	-	-	21.52	-	-
Sig.	*	*	*	ns	*	*
CV%	8.92	11.56	13.26	8.21	6.26	7.13

Each data point represents a mean of 3 samples. SPEB= sealed polyethylene bag, EPEB= Evacuated polyethylene bag, Amb= Ambient temperature, ns= no significant difference. *= $p<0.05$ significant, Trt.= treatment, Cont= Control, Sig= significant effect Treatment means having similar letter in the same column show no significant difference by DMRT by 5 %.

Increasing acidity commence with ripening. Organic acids form during ripening process increase the acidity of bananas. No significant differences in

acidity among treatments in ripened fruits showed that organic acid formation has been controlled by storing these bananas in modified atmosphere at low temperature.

Table 6. Titrable acidity of 'Kolikuttu bananas stored at 10 °C and 15 °C for 10, 20 and 30 days

Treatment	Titrable acidity (meq/ 100g)					
	Storage time			After inducing ripening		
	10 days	20 days	30 days	10 days	20 days	30 days
10 °C						
SPEB	2.28b	2.40b	1.96b	14.74	15.05	14.82
EPEB	2.22b	2.07b	2.01	15.52	14.36	14.21
Cont	2.19b	2.19b	2.13b	15.05	14.92	14.89
15 °C						
SPEB	2.34b	2.10b	2.34b	14.89	13.83	14.21
EPEB	2.10b	2.19b	2.65b	15.44	14.97	14.59
Cont	2.43b	8.41a	15.21a	14.21	15.21	15.05
Amb						
SPEB	14.89a	-	-	15.21	-	-
EPEB	2.52b	-	-	16.00	-	-
Cont	15.92a	-	-	15.92	-	-
Sig.	*	*	*	ns	ns	ns
CV%	6.28	24.32	18.93	6.31	16.66	4.93

Each data point represents a mean of 3 samples. SPEB= sealed polyethylene bag, EPEB= Evacuated polyethylene bag, Amb= Ambient temperature, ns= no significant difference. Trt.= treatment, Cont= Control, Treatment means having similar letter in the same column show no significant difference by DMRT by 5 %.

Sensory evaluation

Table 7 shows that the aroma of ripened fruits has significantly declined in all bananas stored at 10 °C. Smoothness of the flesh of ripened bananas stored at 15 °C was higher than that stored at 10 °C irrespective of duration of storage (Table 8). Sweetness of ripened banana was high in fruits stored at 15 °C regardless of duration of storage with compared to that at 10 °C.

Table 7. Ranksum values of flesh color and aroma of ripened bananas stored at 10 °C for 10, 20 and 30 days.

Treatment	Rank Value					
	Flesh color			Aroma		
	10 days	20 days	30 days	10 days	20 days	30 days
10 °C						
SPEB	6.3	4.0	5.1	5.9	2.1	2.6
EPEB	6.0	4.9	5.6	6.4	3.6	4.5
Cont	6.2	2.7	2.3	5.6	4.0	3.2
15 °C						
SPEB	6.9	6.5	6.4	7.0	6.0	6.8
EPEB	7.0	7.3	7.0	6.5	6.4	7.0
Cont	7.0	5.7	5.9	5.2	5.8	5.7
Amb						
SPEB	-	-	-	6.3	-	-
EPEB	-	-	-	5.2	-	-
Cont	-	-	-	5.7	-	-
Sig.	0.05	0.05	0.01	0.05	0.01	0.01

Each data point representative a mean of 3 samples. SPEB = sealed polyethylene bag, EPEB = evacuated polyethylene bag, Amb = ambient temperature.

Table 8. Sum of rank values of smoothness and sweetness of ripened 'Kolikuttu' bananas stored at 10 °C and 15 °C for 10, 20 and 30 days.

Treatment	Sum of Rank Values					
	Smoothness			Sweetness		
	10 days	20 days	30 days	10 days	20 days	30 days
10 °C						
SPEB	6.0	1.2	1.1	6.0	3.4	3.5
EPEB	6.7	1.6	1.4	6.0	4.3	4.3
Cont	3.7	3.1	2.6	5.1	1.2	3.3
15 °C						
SPEB	7.0	6.3	4.9	6.6	5.8	6.1
EPEB	7.0	7.0	6.9	5.9	6.5	7.0
Cont	7.0	5.8	6.1	6.3	4.8	4.4
Amb						
SPEB	6.9	-	-	6.6	-	-
EPEB	5.7	-	-	5.0	-	-
Cont	6.0	-	-	5.2	-	-
Sig.	0.05	0.05	0.01	0.05	0.01	0.01

Each data point represents a mean of 3 samples. SPEB = sealed polyethylene bag, EPEB = evacuated polyethylene bag, Amb. = ambient temperature.

Although modified atmosphere increased the storage life of Kolikuttu bananas, modified atmosphere should be combined with low temperature (15 °C) to increase the storage life. Both types of modified atmosphere delayed the peel color development, total soluble solids formation and organic acid formation at either at 10 °C or 15 °C. Poor eating quality of fruits stored at 10 °C does not permit to store bananas at that temperature. In addition to poor sensory parameters and the external color was also badly affected due to chilling injury at later part of the storage period.

Very short storage life of Kolikuttu bananas at ambient temperature, observed in this experiment was similar to observations made for Embul bananas (Sarananda, 1989). Low oxygen and high carbon dioxide environment created in sealed polythene bags through the process of respiration of bananas would have decrease the rate of respiration, hence ripening would have been delayed (Mc Glasson and Wills, 1972). Ethylene is a ripening hormone which is essential to initiate the ripening process of bananas (Burg and Burg, 1969). Delay in ethylene production in the presence of low oxygen and high carbon dioxide when compared to atmospheric composition (Yang and Hoffman, 1984) would have delayed the ripening process of modified atmosphere stored bananas. Similar results had been observed for Cavendish bananas when they were stored in modified atmosphere using sealed polyethylene bags and stored at low temperature, thus confirming our results on Kolikuttu bananas (Scott and Gandegengara, 1974). Based on these results it can be concluded that Kolikuttu bananas can not be stored in modified atmosphere at low temperatures such as 10 °C, while this variety of banana can be exported by sea when stored in bags in modified atmosphere using sealed polyethylene bags and in evacuated polyethylene bags, at 15 °C.

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