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Controlled Atmosphere Storage of '*Embul*' Bananas

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ABSTRACT. The effects of low oxygen levels on 'Embul' variety bananas stored at 13.5°C were examined. Concentrations of 1%, 3%, 5% and 7% were compared with a control atmospheric oxygen level of 21%. Weight loss, storage life, external appearance, eating quality and incidence of crown-rot of 'Embul' variety bananas were recorded at 13.5°C. The weight loss of bananas stored at 1%, 3% and 5% oxygen levels was minimum compared to fruits stored at 21% oxygen (control) and at 7% oxygen which had a higher weight loss throughout the storage period. Storage life, external appearance and eating quality of ripe fruits were similar when fruits were stored at 1% , 3% and 5% levels of oxygen. Low oxygen at a concentration of 7% did not extend the storage life, while physico-chemical parameters of these fruits were comparable with those of the controls. However, physico-chemical parameters of ripe fruits stored at all low oxygen levels were similar to those of fruits maintained under ambient conditions (control). The incidence of crown-rot in green fruits stored at 1%, 3% and 5% oxygen was significantly lower, compared with fruits stored at 7% oxygen and the fruits stored at 21% oxygen. Crown-rot was observed in ripe fruits stored at 1%, 3% and 5% oxygen levels. The incidence of crown-rot on ripe fruits was also observed to be lower at these concentrations compared with fruits stored at 7% and 21% oxygen.

INTRODUCTION

'*Embul*' bananas grown in Sri Lanka have a high export potential due to their small size and characteristic flavour. The inherent capacity of this crop to grow in diverse weather conditions, higher yield potentials and resistance to diseases such as, Sigatoka, encourage Sri Lankan farmers to grow this cultivar. Short storage life and crown-rot caused by several fungi are the major problems associated with the export of this commodity.

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Although refrigerated storage at 13.5°C extends the storage life, certain precautions have to be taken in order to eliminate the risk of the condition 'ship ripe' during the voyage.

Uniform maturity at harvest can be maintained by tagging operations. However, physiological maturity may differ due to non-uniform agronomic practices which results in pre-mature ripening. Therefore, refrigerated transport itself may not provide adequate storage life for bananas during long distance transport.

Controlled Atmospheric (CA) storage is fast becoming a popular technique for extending the storage life of fresh fruits and vegetables. It is becoming more and more popular and could be used for storing bananas. No CA work has been reported on '*Embul*' bananas grown in Sri Lanka. Although fungicide dip or application of fungicide pad could prevent the crown-rot caused by fungi, chemical treated fruits are not encouraged by the European market. Therefore, this study was carried out to find out the effect of low oxygen on extending the storage life of '*Embul*' bananas while minimizing the incidence of crown-rot.

MATERIAL AND METHODS

'*Embul*' variety bananas were harvested 12 weeks after flowering, dehanded in the field and transported to CISIR, Colombo at an ambient temperature (28-30°C) on the same day. On the following day 10 hands were randomly selected, weighed and transferred into glass cubicles each of 90 l capacity. Cubicles were sealed to provide uniform gaseous compositions. Five cubicles were used for the experiment and were stored at 13.5°C. A continuous flow of each gas mixture at the rate of 20 l/h was maintained within the chambers. Gas mixtures used for the experiment were 1%, 3%, 5% and 7% oxygen in nitrogen. Atmospheric air was used as the control treatment.

Cubicles were unsealed after 20 and 30 days of storage. Hands were then weighed to record the weight loss. Incidence of crown-rot was recorded using an index, 0-4 where 0=no rot, 4=rot extending up to the neck of fingers. The Colour Index (CI) of fruits was measured using a 1-7 scale where 1=green and 7=over ripe. Fruit firmness was measured in the middle 1/3 region of the finger using a Labsco firmness tester having a 2 mm probe.

Ten grams of pulp from the middle 1/3 of a finger was homogenized with 40 ml of distilled water and the filtrate used to measure total soluble solids (TSS) and titratable acidity (TA). A few drops of the filtrate was used to measure total soluble solids using a hand held refractometer. A volume of 10 ml of the filtrate was titrated against standard 0.1 N NaOH and the acidity was expressed as Malic acid. Ripening was induced in the remaining fruits using calcium carbide at the rate of 1 g/4 l space. At the ripening stage of Colour Index (CI) 6 fruits were tested for crown-rot, and the other physico-chemical parameters described above. The eating quality of the ripe fruit was also recorded using a trained tasting panel. The experimental design used was a complete randomized design and mean separation was done using DMRT at a 5% probability level.

RESULTS AND DISCUSSION

After 20 days in storage at 13.5°C, a higher weight loss was observed in fruits stored at 7% oxygen and in the control treatment (Table 1). The peel colour of fruits stored at 7% oxygen and in the controls maintained at 21% oxygen increased, indicating that fruits began to ripen after 20 days. Peel colour development did not progress in fruits stored at 1%, 3% and 5% oxygen even after 30 days. Furthermore, low oxygen minimized weight loss when compared to 7% oxygen and at the control level of 21% oxygen. A higher respiration rate of the fruits during ripening resulted in a higher moisture loss. The decline in dry matter content resulted in a higher weight loss.

As shown in Table 2, with the progression of peel colour, fruit firmness declined and TSS increased as suggested by Simonds (1976). There was no change in firmness and TSS in fruits stored at 1%, 3% and 5% oxygen. However, firmness declined and TSS increased in fruits stored at 7% oxygen and under controlled conditions at 21% oxygen after 20 days of storage. Low oxygen concentrations of 1%, 3% and 5% did not initiate the ripening process in bananas even after 30 days of storage.

Titratable acidity of the pulp increased as ripening progressed (Simonds, 1966). There was no increase in acidity (Table 3) in fruits stored at 1% and 3% oxygen after 20 days of storage. Higher acidity of fruits stored at 7% oxygen and 21% oxygen confirmed that ripening had begun. It has been found out that low oxygen delays the climateric rise in Cavendish bananas (Mc Glasson and Wills, 1972). Apart from the delay in ethylene

Table 1. Percentage weight loss and colour index of bananas (square root transformation) during storage at 13.5°C under different oxygen concentrations.

Treatment	% Weight loss		Colour index	
	Storage time in days		Storage time in days	
	20	30	20	30
1% oxygen	1.34^{c}	1.39^{b}	1.00^{b}	1.00^{a}
3% oxygen	1.49^{c}	3.00^{a}	1.00^{b}	1.00^{a}
5% oxygen	1.18^{c}	2.80^{a}	1.00^{b}	1.00^{a}
7% oxygen	1.77^{b}	-	2.23^{a}	-
21% oxygen (Control)	3.72^{a}	-	2.04^{a}	-

Treatment means in a column having a common letter(s) are not significantly different by DMRT 5%. Each data point represents average of 5 samples.
Colour Index: 1=green, 2=colour break, 3=more green than yellow, 4=more yellow than green, 5=yellow with green tip, 6=full yellow

Table 2. Average fruit firmness (kPa) and total soluble solids (Brix %) of bananas during storage at 13.5°C under different oxygen concentrations.

Treatment	Fruit firmness (kPa)		TSS (Brix %)	
	Storage time in days		Storage time in days	
	20	30	20	30
1% oxygen	1.93^{a}	1.87^{a}	6.20^{b}	6.80^{a}
3% oxygen	1.84^{a}	1.61^{b}	7.00^{b}	6.70^{a}
5% oxygen	1.75^{a}	1.47^{b}	6.50^{b}	7.60^{a}
7% oxygen	0.56^{c}	-	10.40^{a}	-
21% oxygen (Control)	1.08^{b}	-	10.60^{a}	-

Treatment means in a column having a common letter(s) are not significantly different by DMRT 5%. Each data point represents an average of 5 samples.

production at low oxygen levels, the reduced energy status of the fruit could also have contributed to the delay in ripening (Yang and Hoffman, 1984). The initiation of ripening in fruits stored at 7% oxygen was similar to that of fruits stored at 21% oxygen and showed that 7% oxygen was higher than the critical level which delayed or inhibited ethylene production. Certain ripening changes were more prominent in fruits stored at 7% oxygen when compared to controls at 21% oxygen. This may be due to stress caused by low oxygen which accelerates ethylene production triggering the climacteric rise (Yang and Hoffman, 1984).

Table 3. Average titratable acidity and crown-rot index (square root transformation) of bananas during storage at 13.5°C under different oxygen concentrations.

Treatment	TA (Malic g/100 g FW)		Crown-rot index			
	Storage time in days		Storage time in days			
	20	30	20		30	
			green	ripe	green	ripe
1% oxygen	0.39[b]	0.42[a]	1.09[b]	1.18[b]	1.09[a]	1.30[a]
3% oxygen	0.35[b]	0.41[a]	1.00[b]	1.26[b]	1.09[a]	1.34[a]
5% oxygen	0.42[a]	0.48[a]	0.89[b]	1.34[b]	1.09[a]	1.48[a]
7% oxygen	0.50[a]	-	1.41[a]	1.54[a]	-	-
21% oxygen (Control)	0.44[a]	-	1.58[a]	1.64[a]	-	-

Treatment means in a column having a common letter(s) are not significantly different by DMRT 5%. Each data point represents average of 5 samples.
Crown-rot index: 0=no rot, 1=5% of the crown affected, 2=50% of the crown affected, 3=75% of the crown affected and 4=100% of the crown affected and the rot extended up to finger stalk.

Crown-rot is primarily caused by fungal species such as, *Colletotrichum musae* (Berk and Curt), *Verticilium arx*, *Fusarium miniliforme* Edwards and *V. theobrome* (Turc.) Mason and Hughes present in the crown (Griffee and Burden, 1976; Knight, 1982). *C. musae* and *F. miniliforme* were most frequently isolated from the rotted crowns of '*Embul*' bananas. It was observed that the incidence of crown-rot was very low in bananas stored at 1%, 3% and 5% oxygen levels compared to 7% oxygen and the control at 21% oxygen, where a higher incidence of rot was observed even in green fruits after 20 days of storage. Progression of rot was observed with ripening

in all crowns. However, the extent of rot was low even in ripe fruits which were stored at 1%, 3% and 5% oxygen. Slow progression of rot into the crown during ripening provided evidence of the fungistatic nature of low oxygen. The fungistatic nature of low oxygen on *Botrytis ali*, *Rhizophus nigricans* and *Penicillium expansum* (Littlefield *et. al.*, 1986) confirmed the decreased progression of rot bananas stored at 1-5% oxygen. The slower progression of rot into the green crown may be due to the lower senescence of crown tissue when compared with controls where senescence had progressed. However, the exact effect of low oxygen on fungal growth has to be studied using inoculated bananas with crown rot causing organisms.

Results of this experiment showed that the storage life of '*Embul*' bananas can be extended up to 30 days by storing them in 1-5% oxygen at 13.5°C. No external and internal qualities of ripe fruits were affected by these forms of low oxygen treatment. The fungistatic nature of low oxygen used in this experiment indicated that the use of fungicide to minimize the incidence of crown rot could be replaced by the introduction of Controlled Atmospheric environments.

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