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Effects of precooling, ethylene absorbent and partial evacuation of air on storage of banana (*Musa* sp. cv. Berangan) under modified atmosphere

[Kesan prapenyejukan, penyerap etilena dan pengeluaran separa udara terhadap penyimpanan pisang (*Musa* sp. kv. Berangan) dengan atmosfera terubahsuai]

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Key words: banana cv. Berangan, precooling, storage, modified atmosphere

Abstrak

Kesan prapenyejukan, penyerap etilena dan pengeluaran separa udara terhadap pisang Berangan yang disimpan di dalam kotak kertas tebal beralur dengan kandungan seberat 10 kg dan 12 kg menurut kaedah atmosfera terubahsuai pada suhu 14 °C telah dikaji. Prapenyejukan dan pengeluaran separa udara dari beg polietilena (PE) yang digunakan didapati tidak perlu untuk menyimpan pisang Berangan. Penyimpanan selama 4 minggu diperoleh hanya dengan membungkus pisang di dalam beg PE yang diikat kemas. Dalam tempoh simpan tersebut, aras CO_2 dan O_2 di dalam kesemua beg PE yang mengandungi pisang adalah pada aras yang selamat dan tidak menjejaskan mutu buah, iaitu masing-masingnya 3.4–6.7% dan 1.6–6.1%. Aras etilena meningkat secara mendadak setelah 4 minggu. Penyimpanan buah selama 5 minggu diperoleh sama ada dengan menggunakan penyerap etilena atau meningkatkan berat pisang di dalam setiap beg. Analisis pH, asid boleh titrat keseluruhan, pepejal larut keseluruhan, kanji dan gula pulpa serta penilaian mutu buah setelah penyimpanan dan pemasakan juga dijalankan.

Abstract

The effects of precooling, ethylene absorbent and partial evacuation of air on banana cv. Berangan with net weights of 10 kg and 12 kg stored under modified atmosphere (MA) in corrugated fibreboard boxes at 14 °C were studied. Precooling and partial evacuation of air were found to be unnecessary for storage of Berangan under MA. Storage of up to 4 weeks was achieved simply by packing the fruit in sealed polyethylene bag. During this period, the levels of CO_2 and O_2 inside the bags containing the banana were within the safe range, i.e. 3.4–6.7% and 1.6–6.1% respectively. Ethylene levels increased drastically after 4 weeks. Storage of up to 5 weeks was obtained either by incorporating ethylene absorbent or increasing the weight of fruit per bag. The analysis on pH, total titratable acidity, total soluble solids, starch and sugar of the pulp as well as evaluation on fruit quality after storage and ripening were also carried out.

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Introduction

Modified atmosphere (MA) storage or packaging of fresh fruits and vegetables has been comprehensively reviewed by Kader et al. (1989). The technology on commercial storage of banana by MA has already been established for Cavendish variety. In Malaysia, the storage system for cv. Mas has also been developed (Anon. 1988; Abdullah et al. 1993). The system is effective in preserving the freshness and greenness of Mas banana for more than 6 weeks. However, a different procedure of packing and storage from the Cavendish was found to be necessary since Mas developed carbon dioxide injury when the same system for the Cavendish was used (Abdullah et al. 1987a; Abdullah, Abd. Shukor, Rohaya et al. 1987, Abdullah et al. 1990). It appears that for safe storage of banana, the level of CO_2 should not exceed 10% and ethylene should not exceed 0.35 ppm while O_2 should remain above 1%. The procedure for Mas banana includes precooling, incorporation of ethylene absorbent and partial evacuation of air during packing. This system has been tested successfully in several commercial trial shipments by sea to Hong Kong, Japan and Denmark (Abdullah et al. 1986; Abdullah et al. 1987b; Abd. Shukor et al. 1989).

Another banana cultivar which is gaining popularity in the international market is Lakatan (Abdullah, Pantastico et al. 1990), which is the equivalent of Malaysian banana cv. Berangan (Valmayor et al. 1990). Berangan has been identified as another potential Malaysian fruit for export. However, to develop the export market, it is necessary to investigate and establish the storage system of this banana cultivar so that it can be used in commercial shipments by sea. The effects of precooling, ethylene absorbent and partial evacuation of air in MA storage of Berangan are reported in this paper.

Materials and methods

Fruit

Banana cv. Berangan of approximately 12–13 weeks from flower emergence were purchased from a private grower in Tangkak, Johor. After harvesting, the fruit were transported immediately to the FAMA Packinghouse Complex in Tangkak for packinghouse operations which comprised removal of flower remnants, dehanding, washing, dipping in 500 ppm benomyl [*Benlate,* a.i. 50% (w/w)] and drying. Only good quality and damage-free fruit were used in the experiments.

Packing

Hands of banana were packed into low density polyethylene (PE) bag (100 cm x 100 cm x 0.04 mm) inside a telescopic corrugated fibreboard (CFB) carton. The banana which weighed either 10 or 12 kg in each bag represented a replicate. Whenever necessary, the fruit were either precooled or the air inside the bag was partially evacuated. Precooling was applied by exposing the fruit in unsealed PE bag to a forced-air precooler set at 8 °C for approximately 70 min until the temperature at the centre of the fruit pulp dropped to 14 °C. The bag was partially evacuated of air by using a vacuum pump before sealed tightly with a string about 15 cm from the opening. Whenever necessary, ethylene absorbent (potassium permanganate in 2 x 20 g sachet of 'Clean pack') was used in the bag.

Experiment 1. Effects of precooling, partial evacuation of air and ethylene absorbent

The fruit were packed by six packing methods:

- sealed in PE bag (control),
- sealed in PE bag with ethylene absorbent,
- sealed in PE bag with ethylene absorbent and partial air evacuation,
- precooled and sealed in PE bag,
- precooled, sealed in PE bag with ethylene absorbent, and

- precooled, sealed in PE bag with ethylene absorbent and partial air evacuation.

The weight of banana in each bag was 10 kg.

Experiment 2. Effects of ethylene absorbent and fruit weight

The fruit at 10 kg and 12 kg in quantity were packed by two packing methods:

- sealed in PE bag, and
- sealed in PE bag with ethylene absorbent.

The 10 kg and 12 kg weights were chosen because they were the standard weights accepted in many international markets. Each treatment was replicated six times with each box of banana as a replicate. Bags having 12 kg of fruit contained two sachets of ethylene absorbent. This experiment did not involve either precooling or partial evacuation of air.

Storage

After packing, the fruit were transported immediately to the postharvest laboratory, Food Technology Research Centre, MARDI, Serdang in FAMA cold truck for storage in a walk-in cold room. The temperature of the cold truck and the cold room was maintained at 14 °C. The fruit were stored for 4 weeks in Experiment 1 and 5 weeks in Experiment 2.

Determination of O_2, CO_2 and ethylene concentrations

One mL of the gas sample was withdrawn each week from each bag with an air tight hypodermic syringe for each gas determination. The gas was injected into a Varian 1420 gas chromatograph fitted with a TCD for O_2 and CO_2 determination. Determination of C_2H_4 was carried out with a Varian 1440 gas chromatograph fitted with a FID.

Evaluation of fruit quality after storage

After removal, the bags were unsealed and the banana were induced to ripen with 1 000 ppm ethylene for 24 h at 25 °C. When the fruit had attained colour index 6 (completely yellow), general quality was evaluated. Total soluble solids (TSS) of the pulp was determined by using a refractometer (HR 1A-Kyowa), pH with a Beckman pH meter, total titratable acidity (TTA) by titrating with 0.1 *N* NaOH solution and expressed as per cent malic acid, and starch and sugar according to AOAC (1970). For this purpose, one finger from each hand in each box was taken and peeled. The pulp was then mixed and blended in a kitchen blender for homogeneity and representative sampling.

Results and discussion

Experiment 1. Effects of precooling, partial evacuation of air and ethylene absorbent

The concentrations of CO_2 and O_2 in the PE bags used for packing the banana were maintained around 3.4–6.7% and 1.6 –6.1% respectively from the first to the fourth week among all treatments *(Table 1)*. Both the concentrations of CO_2 and O_2 were within the safe range for storage under MA. Apparently, the bag with ethylene absorbent had slightly lower concentration of CO_2, whereas partial evacuation of air and precooling did not have any influence on the concentration of the gas. The influence of ethylene absorbent, partial evacuation of air and precooling on the concentration of O_2 was not obvious.

The C_2H_4 concentrations were relatively low in all treatments during the first 3 weeks of storage. The levels increased drastically on the fourth week. The bags without ethylene absorbent tended to have higher levels of the gas. Precooling and partial evacuation of air were not found to have any significant influence on the concentrations of C_2H_4.

After 4 weeks of storage, all fruit, despite the treatments given, remained green and firm. The fruit ripened satisfactorily

Table 1. Effects of precooling, partial evacuation of air and ethylene absorbent on the concentrations of CO_2, O_2 and C_2H_4 in sealed PE bags containing banana cv. Berangan during storage at 14 °C*

Gas	Treatment**	Storage period (weeks)				
		0	1	2	3	4
CO_2 (%)	A	0.03aC	6.6aA	6.4aA	6.7aA	5.3aB
	B	0.03aC	6.1aA	6.3aA	6.0bA	4.3bB
	C	0.03aD	5.3bB	6.0aA	6.2abA	4.3bC
	D	0.03aC	4.9bB	5.9aA	6.2abA	4.9abB
	E	0.03aC	5.2bB	6.0aA	6.0bA	4.7abB
	F	0.03aD	5.1bB	5.8aA	6.0bA	3.4bC
O_2 (%)	A	21.0aA	3.4aB	3.0aB	2.6abB	4.0abB
	B	21.0aA	1.9aD	1.8aD	3.2abC	5.2abB
	C	21.0aA	2.8aC	2.7aC	4.9aB	6.1aB
	D	21.0aA	1.8aB	1.6aB	1.6bB	2.9bB
	E	21.0aA	3.0aCD	1.6aD	3.6abC	5.5abB
	F	21.0aA	3.6aBC	2.7aC	3.9abBC	5.1abB
C_2H_4 (ppm)	A	0.0aC	0.10aB	0.05abB	0.10aB	0.44aA
	B	0.0aD	0.08bB	0.04bC	0.05bBC	0.25bA
	C	0.0aD	0.08bB	0.05abC	0.04bC	0.27bA
	D	0.0aC	0.10aB	0.07aB	0.07abB	0.45aA
	E	0.0aC	0.08bB	0.03bB	0.05bB	0.36abA
	F	0.0aC	0.07bB	0.04bB	0.05bB	0.25bA

*Each value is the mean of 6 replicates. Values with the same small letters vertically and capital letters horizontally for each gas are not significantly different at 5% level by DMRT

**A = sealed in PE bag
B = sealed in PE bag with ethylene absorbent
C = sealed in PE bag with partial air evacuation and ethylene absorbent
D = precooled, sealed in PE bag
E = precooled, sealed in PE bag with ethylene absorbent
F = precooled, sealed in PE with partial air evacuation and ethylene absorbent

after being induced with 1 000 ppm external C_2H_4 at 25 °C without showing any symptoms of physiological disorder. There were slight differences in the major chemical compositions of the pulp i.e. TTA, pH, starch and sugar but the values of TSS were not significantly different between treatments *(Table 2)*. TSS has been commonly used as one of the most important quality criteria for banana in Japan. The data indicate that the fruit quality with regard to the TSS content was almost the same despite the differences in the storage treatments given.

These results showed that Berangan banana can be stored for 4 weeks under MA at 14 °C without precooling, partial evacuation of air and ethylene absorbent. This is almost similar to the commercial storage method of Cavendish banana practised in the Philippines for long distance shipment. The storage method used in the Philippines only incorporates partial evacuation of air and known as vacuum packing (Pantastico et al. 1990). It is also much simpler than the procedure recommended for banana cv. Mas which develops CO_2 injury when stored under MA (Abdullah et al. 1987a; Abd. Shukor et al. 1989). Berangan banana is almost similar to Cavendish but differs from Mas in the response to MA storage as a result of its respiratory behaviour. Berangan banana has a longer preclimacteric period than Mas but is about the same as that for Cavendish (Abdullah, Lizada et al. 1990).

Table 2. Chemical compositions of ripe banana cv. Berangan after 4 weeks of storage in modified atmosphere at 14 °C*

Treatment**	TTA (%)	pH (%)	TSS (%)	Starch (%)	Sugar
A	0.46a	5.3c	22.3a	6.6bc	12.4a
B	0.45a	5.5b	22.9a	5.7c	12.6a
C	0.45a	5.5b	21.9a	6.7bc	12.6a
D	0.29b	5.5b	22.9a	7.0b	10.3b
E	nd	6.7a	22.2a	7.3b	12.2a
F	0.48a	4.9d	21.7a	8.6a	12.3a

*Each value is the mean of 6 replicates. Values with the same letters are not significantly different by DMRT
**Treatments same as in *Table 1*
nd = not done

Experiment 2: Effects of ethylene absorbent and fruit weight

Weekly changes in the concentrations of CO_2, O_2 and C_2H_4 in PE bags containing 10 and 12 kg of banana cv. Berangan packed without precooling and partial evacuation of air are presented in *Table 3*. The concentrations of CO_2 in the sealed PE bags containing 10 kg and 12 kg of bananas with or without ethylene absorbent increased from 0.03% initially to 4.0–5.9% after 1 week of storage. Between 1 and 5 weeks of storage, the CO_2 concentrations were maintained within the safe range, i.e. around 4.0–6.9% in all treatments. On the other hand, the O_2 levels in all treatments decreased drastically after 1 week of storage. Greatest reduction was observed in bags containing 12 kg of fruit (with and without ethylene absorbent) and 10 kg of fruit with ethylene absorbent. Between 1 and 5 weeks, the O_2 concentrations tended to increase in all treatments. However, bags containing 10 kg weight without ethylene absorbent recorded the highest increase, whereas the increase in the other three treatments were lower and maintained at about the same levels. The concentrations of C_2H_4 were lower in the bags containing 12 kg of bananas. The lower level of C_2H_4 were maintained until the fifth week. On the other hand, the levels of C_2H_4 in the bags having 10 kg of fruit increased continuously during storage.

After 5 weeks of storage, 50% of the 10 kg fruit in the sealed bags without ethylene absorbent had already ripened prematurely in the storage room, whereas the fruit of other treatments were still green and firm *(Table 4).* All the green fruit ripened satisfactorily after being induced with 1 000 ppm of external C_2H_4. The partly ripe 10 kg fruit from the bags without ethylene absorbent did not ripen satisfactorily after further induction with ethylene.

The premature ripening of 10 kg banana in the bags without ethylene absorbent after 5 weeks could have been due to higher concentrations of O_2 and C_2H_4 during the later stage of storage. This condition was probably sufficient to trigger off ripening. This problem was not observed in the bags with 12 kg of fruit. Higher O_2 concentration in the bags containing 10 kg of fruit was probably due to the combined effect of a greater headspace besides the lower total respiration of fruit compared with the bags with 12 kg of fruit, as bags of the same size were used. When the concentration of O_2 was higher, the fruit were exposed to an environmental condition where the production of C_2H_4 was less restricted. As the storage time extended, the concentration of C_2H_4 increased to a level which can trigger fruit ripening unless ethylene absorbent was placed inside the bags. This explains the premature ripening

Table 3. Effects of fruit weight on the concentrations of CO_2, O_2 and C_2H_4 in PE bags containing banana cv. Berangan during storage at 14 °C*

Gas	Treatment**	Storage period (weeks)					
		0	1	2	3	4	5
CO_2 (%)	A	0.03aD	4.0aBC	3.3bC	5.3aAB	5.8aA	6.0aA
	B	0.03aC	5.9aA	4.9aAB	4.7aB	5.6aAB	6.0aA
	C	0.03aC	4.9aB	4.4abB	5.2aB	5.4aB	6.9aA
	D	0.03aC	5.2aAB	4.8aB	4.8aB	5.1aAB	6.0aA
O_2 (%)	A	21.1aA	6.2aC	8.1aBC	9.3aBC	9.0aBC	10.5aB
	B	21.1aA	2.8bC	4.2aBC	4.6bBC	4.8aBC	6.0abB
	C	21.1aA	1.5bC	3.0aB	3.9bB	4.1aB	4.3bB
	D	21.1aA	3.4abD	4.0aCD	4.3bCD	4.8aC	6.4abB
C_2H_4 (ppm)	A	0.0aD	0.08aC	0.18aBC	0.50aBC	0.84aAB	1.30aA
	B	0.0aC	0.09aB	0.18aAB	0.17abAB	0.28aAB	0.64abA
	C	0.0aC	0.05aB	0.06aB	0.10bAB	0.09aAB	0.28bA
	D	0.0aB	0.06aA	0.07aA	0.08bA	0.06aA	0.17bA

*Each value is the mean of 6 replicates. Values with the same small letters vertically for each gas and capital letters horizontally are not significantly different at 5% level by DMRT

**A = 10 kg in sealed PE bag
B = 10 kg in sealed PE bag with ethylene absorbent
C = 12 kg in sealed PE bag
D = 12 kg in sealed PE bag with ethylene absorbent
The treatments did not involve precooling and partial evacuation of air

Table 4. General quality of banana cv. Berangan after 5 weeks of storage in modified atmosphere at 14 °C and after ripening induction with 1 000 ppm ethylene at 25 °C

Treatment*	After storage	After ripening induction
A**	3 out of 6 boxes had ripened. The other 3 boxes were still green and firm.	Ripen satisfactorily
B	Green and firm	Ripen satisfactorily
C	Green and firm	Ripen satisfactorily
D	Green and firm	Ripen satisfactorily

*Treatments same as in *Table 3*

**Fruit ripened during removal from storage room were discarded

which took place in the bags containing 10 kg of fruit without ethylene absorbent. Effect of ethylene absorbent in MA storage has been reported on several other banana varieties including Mas (Abdullah et al. 1987a), Cavendish (Scott and Gandanegara 1974; Lizada et al. 1987) and Saba (Tiangco et al. 1987).

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