Improvement on storage of banana (Musa sp. cv. Mas) under modified atmosphere

[Penambakan kaedah penyimpanan pisang (Musa sp. kv. Mas) dengan atmosfera terubahsuai]

H. Abdullah*, M. A. Rohaya* and J. Mohd. Yunus**

Key words: banana cv. Mas, storage, modified atmosphere

Abstrak

Kajian terhadap penambahkaan kaedah penyimpanan pisang Mas dengan sistem atmosfera terubahsuai telah dilakukan. Pisang Mas pada peringkat kematangan 7–8 minggu dari tempoh berjantung disirs, dibasuh, direndam di dalam 500 ppm benomil dan dikerikan sebelum dimasukkan ke dalam beg polietilena berketumpatan rendah (LDPE) di dalam kotak kertas tebal beralur. Berat pisang di dalam kotak yang digunakan ialah 5 kg dan 10 kg. Semua perawatan disistrakan prapenyejukan pada suhu 8 °C, penggunaan penyerap etilena dan pengeluaran separa udara sebelum beg tersebut diikat kemas. Suhu penyimpanan ialah 14 °C. Selepas 4 minggu, buah yang disimpan dengan berat 10 kg/kotak mengalami kecederaan CO2 manakala buah yang beratnya 5 kg/kotak tidak mengalami kecederaan tersebut sehingga 6 minggu penyimpanan. Kejadian kecederaan CO2 dipengaruhi oleh kandungan CO2, O2 dan C2H4 di dalam beg LDPE. Penyimpanan dalam bentuk sisir atau gugus tidak mempengaruhi mutu akhir buah.

Abstract

Improvement studies on a storage method for the banana cv. Mas under modified atmosphere were carried out. Fruit at maturity stage of 7–8 weeks from flower emergence were dehanded, washed, dipped in 500 ppm benomyl and dried before packing into low density polyethylene (LDPE) bags in corrugated fibreboard boxes. The weight of banana in the bags were either 5 kg or 10 kg. Treatments included precooling at 8 °C, the use of ethylene absorbent in storage bags and partial evacuation of air before tight sealing of bags. Storage temperature was 14 °C. After 4 weeks, the fruit packed in 10 kg/box developed CO2 injury, whereas no such injury was detected with fruit packed in 5 kg/box even after 6 weeks of storage. The occurrence of CO2 injury was influenced by the content of CO2, O2 and C2H4 inside the LDPE bags. Packing of banana either in the form of hands or clusters did not influence the final quality of the fruit.
**Introduction**

Modified atmosphere (MA) storage is a method which can be used in conjunction with refrigeration to enhance storage life of some fruits and vegetables (Kader et al. 1989). The underlying principle involved in MA storage is the modification of relative concentrations of CO$_2$ and O$_2$ to appropriate levels, in the atmosphere in which the produce is placed. A modified atmosphere can be created by storing fruits in sealed permeable films such as low density polyethylene (LDPE) bags. As a result of respiration, an atmosphere high in CO$_2$ and low in O$_2$ will ensue with time. Ethylene, a natural gas emitted by fruit which can trigger ripening, can be reduced or eliminated by ethylene absorbent placed in the storage bag (Hardenburg et al. 1990).

With regard to banana, refrigeration at 10–14 °C alone is only sufficient to preserve the greenness of the fruit for 10–34 days (Abdullah et al. 1990). The use of MA in combination with refrigeration can further extend the storage life and hence allows the fruit to be economically transported by sea to distant markets. This method has been applied commercially to transport Cavendish banana from South America to Japan (Shibata, O., Japan Fresh Fruits, Tokyo, pers. comm. 1987) and from the Philippines to West Asia (Roperos, J., Twin Rivers Research Centre, Davao, Philippines, pers. comm. 1984).

The response of banana to MA storage is highly influenced by many factors, especially the variety. Banana cv. Mas when stored by using the same procedure, as has been practised for the Cavendish, tended to develop CO$_2$ injury when allowed to ripen under normal condition (Abdullah, Abd. Shukor, Rohaya et al. 1987; Abdullah et al. 1990). The symptoms and causes of the disorder have been described by Pantastico et al. (1990). To prevent such disorder, the atmosphere inside the bag should be regulated to levels tolerable by the fruit. It appears that CO$_2$ should not exceed 10% while O$_2$ should remain above 1% and ethylene must not exceed 0.35 ppm (Abdullah, Abd. Shukor, Rohaya et al. 1987). Based on this information, an effective 4-week storage system for Mas banana was developed and tested commercially in several trial shipments to Hong Kong and Japan during 1985–87 (Abdullah, Abd. Shukor, Mohd. Salleh et al. 1987). Since 1988, studies have been extended to further improve the storage system of banana so that it can also be used for export shipment by sea to Europe. Besides allowing a longer storage period, a viable system must also be able to fit easily into the existing practices of handling and marketing of banana in Europe. The improvement on storage technology of Mas banana via MA is discussed in this paper.

**Materials and methods**

**Fruit**

Banana cv. Mas of approximately 7–8 weeks from flower emergence were purchased from a private grower in Tangkak, Johor. The freshly harvested fruit were immediately transported to the FAMA Complex in Tangkak for packinghouse operations. These comprised the removal of flower remnants, dehanding, washing, dipping in 500 ppm benomyl [Benlate a.i. 50% (w/w)] and drying. Some banana hands were cut into clusters weighing about 500 g each. After drying, the fruit were placed into LDPE bags inside telescopic corrugated fibreboard (CFB) boxes. The fruit were precooled in a forced-air precooler set at 8 °C in unsealed LDPE bags for 70 min. When the pulp temperature had dropped to 14 °C, ethylene absorbents (Cleanpack 20 g sachet) were placed inside the bags. The air inside the bags was partially evacuated by using a household vacuum cleaner followed by sealing the bags approximately 15 cm from the opening.
Experiment 1: Effects of fruit weight and packing form
The fruit were divided into:
- hands weighing a total of 10 kg,
- hands weighing a total of 5 kg, and
- clusters weighing a total of 5 kg.

All fruit were placed in LDPE bags measuring 100 cm x 100 cm x 0.04 mm for 10 kg weight and 80 cm x 80 cm x 0.04 mm for 5 kg weight. The 10 kg packing contained two sachets of ethylene absorbents, whereas the 5 kg packing contained only one sachet. Each treatment was replicated 10 times with each bag in a box representing a replicate.

Experiment 2: Effect of individual wrapping of hands and clusters
This experiment comprised four treatments, namely
- unwrapped hands,
- unwrapped clusters,
- hands wrapped in perforated LDPE bags, and
- clusters wrapped in perforated LDPE bags.

The hands or clusters, individually wrapped or unwrapped, were arranged neatly in LDPE bags inside the CFB boxes. The thickness of perforated bags used to wrap the hands and the clusters was 0.015 mm with 1% perforations. The weight of fruit in each bag for all treatments was 5 kg and contained one 20 g sachet of ethylene absorbent. Each treatment was replicated 10 times.

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 the cold room. The temperature of the truck and the cold room was maintained at 14 °C. In Experiment 1, the storage period was 4 weeks while in Experiment 2, it was 6 weeks.

Determination of O₂, CO₂ and C₂H₄ contents
One mL of the gas sample from each bag was withdrawn weekly with an airtight hypodermic syringe for each gas determination. The gas was injected into a Varian 1420 gas chromatograph fitted with a thermal conductivity detector and a stainless steel column of 150 cm x 3 mm packed with 80–100 mesh Porapak R for CO₂ determination. The carrier gas for CO₂ determination was helium with a flow rate of 30 mL/min and the column temperature was 35 °C. For O₂, a 150 cm x 3 mm stainless steel column packed with molecular sieves 5A mesh 45/60 was used. The flow rate of the carrier gas was similar to that for CO₂. Determination of C₂H₄ was carried out by injecting 1 mL of the gas sample into a Varian 1440 gas chromatograph fitted with a flame ionization detector and a stainless steel column of 180 cm x 4 mm, packed with 100–120 mesh Porapak T. The carrier gas for C₂H₄ determination was nitrogen with a flow rate of 30 mL/min and the column temperature was 100 °C.

Evaluation of fruit quality after storage
After removal from storage, the bags were unsealed and the bananas were induced to ripen with 50 ppm exogenous ethylene for 24 h at 25 °C. Perforated bags used to wrap banana hands or clusters in some of the treatments were not removed during ripening. When the fruit had ripened between colour index 5 and 6 (Lizada et al. 1990), peel and pulp colour, texture, taste, peeling characteristics and overall acceptability were evaluated by using a hedonic scale from 1 to 7 (1 = very bad, 7 = very good). The presence of CO₂ injury was determined according to the symptoms as described by Pantastico et al. (1990). The total soluble solids of the pulp was determined by using a refractometer (HR 1A-Kyowa). For this purpose, one finger without peel, from each hand of banana in
each box was mixed and blended with a kitchen blender.

**Results**

**Effects of fruit weight and packing form**

As shown in Table 1, CO₂ levels in all treatments increased after 1-week storage. However, the level was highest in the bags containing 10 kg of fruit, whereas the levels were about the same in the bags with 5 kg of fruit packed either in hands or clusters. The CO₂ concentrations during 2–4 weeks of storage were similar to those of the first week, thus showing that CO₂ equilibrium was already achieved after the first week.

Coinciding with changes in CO₂ concentration, O₂ levels decreased very sharply after 1 week of storage in all treatments. Bags with 10 kg of fruit had lower O₂ level than those with 5 kg of fruit. However, there was no significant difference between bags containing banana of same weight but packed either as hands or clusters. As the storage period was extended, O₂ in the bags with 10 kg of fruit continued to decrease. After 4 weeks, the O₂ level was considered injurious to the fruit. On the other hand, the O₂ levels in the bags having 5 kg of fruit were always maintained within the safe range i.e. 1.9–3.6%.

The built-up of C₂H₄ was higher in the 10 kg than in the 5 kg bags. This trend was maintained throughout storage. Fruit from all treatments were still green and fresh when they were removed from storage. However, fruit packed in 10 kg/bag thereafter developed CO₂ injury when allowed to ripen at 25 °C under normal atmosphere. The fruit failed to ripen satisfactorily, developed brown coloured peel with black spots, and were infected by fungi. On the other hand, fruit packed in 5 kg/bag ripened normally without developing any CO₂ injury or other disorders.

**Effect of individual wrapping of 5 kg hands and clusters**

In LDPE bags containing 5 kg of banana packed by four methods and stored for up to 6 weeks at 14 °C, the concentrations of CO₂, O₂ and C₂H₄ were maintained at 4.0–5.4%, 2.6–5.9% and 0.05–0.28 ppm.

<table>
<thead>
<tr>
<th>Storage period (weeks)</th>
<th>Treatment</th>
<th>CO₂ (%)</th>
<th>O₂ (%)</th>
<th>C₂H₄ (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Hands, 10 kg</td>
<td>0.03d</td>
<td>21.1a</td>
<td>0.0d</td>
</tr>
<tr>
<td></td>
<td>Hands, 5 kg</td>
<td>0.03d</td>
<td>21.1a</td>
<td>0.0d</td>
</tr>
<tr>
<td></td>
<td>Clusters, 5 kg</td>
<td>0.03d</td>
<td>21.1a</td>
<td>0.0d</td>
</tr>
<tr>
<td>1</td>
<td>Hands, 10 kg</td>
<td>8.4a</td>
<td>1.5c</td>
<td>0.42a</td>
</tr>
<tr>
<td></td>
<td>Hands, 5 kg</td>
<td>5.0b</td>
<td>2.5b</td>
<td>0.33ab</td>
</tr>
<tr>
<td></td>
<td>Clusters, 5 kg</td>
<td>5.5b</td>
<td>2.2bc</td>
<td>0.28b</td>
</tr>
<tr>
<td>2</td>
<td>Hands, 10 kg</td>
<td>7.6a</td>
<td>1.3b</td>
<td>0.73a</td>
</tr>
<tr>
<td></td>
<td>Hands, 5 kg</td>
<td>5.9b</td>
<td>2.1b</td>
<td>0.51b</td>
</tr>
<tr>
<td></td>
<td>Clusters, 5 kg</td>
<td>5.5b</td>
<td>1.9b</td>
<td>0.42b</td>
</tr>
<tr>
<td>3</td>
<td>Hands, 10 kg</td>
<td>6.8a</td>
<td>1.5b</td>
<td>0.57a</td>
</tr>
<tr>
<td></td>
<td>Hands, 5 kg</td>
<td>5.6b</td>
<td>2.5b</td>
<td>0.50a</td>
</tr>
<tr>
<td></td>
<td>Clusters, 5 kg</td>
<td>5.1b</td>
<td>2.9b</td>
<td>0.43a</td>
</tr>
<tr>
<td>4</td>
<td>Hands, 10 kg</td>
<td>6.9a</td>
<td>0.5c</td>
<td>0.49a</td>
</tr>
<tr>
<td></td>
<td>Hands, 5 kg</td>
<td>5.2b</td>
<td>3.4b</td>
<td>0.36a</td>
</tr>
<tr>
<td></td>
<td>Clusters, 5 kg</td>
<td>4.8c</td>
<td>3.6b</td>
<td>0.32a</td>
</tr>
</tbody>
</table>

Each value is the mean of 10 replicates. Mean values with the same letters in the same column are not significantly different at 5% level by DMRT
respectively throughout storage (Table 2). These levels are considered ideal for storage. Wrapping the individual hand or cluster in perforated PE bags did not alter the individual gas concentration in the sealed storage bag. All fruit ripened satisfactorily after exogenous application of 50 ppm C$_2$H$_4$ at 25 °C (Table 3).

Apparently, the fruit wrapped in perforated PE bags had a better skin appearance than the unwrapped ones, being glossy and very bright golden yellow in colour. All fruit were highly acceptable organoleptically. In addition, the total soluble solids were maintained at around 25% levels, almost similar to unstored ripe fruit.

Table 2. Effect of individual wrapping of hands or clusters of banana cv. Mas on the concentrations of CO$_2$, O$_2$ and C$_2$H$_4$ in LDPE bags during storage at 14 °C

<table>
<thead>
<tr>
<th>Storage period (weeks)</th>
<th>Treatment</th>
<th>CO$_2$ (%)</th>
<th>O$_2$ (%)</th>
<th>C$_2$H$_4$ (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>A</td>
<td>0.03b</td>
<td>21.1a</td>
<td>0.0b</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>0.03b</td>
<td>21.1a</td>
<td>0.0b</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>0.03b</td>
<td>21.1a</td>
<td>0.0b</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>0.03b</td>
<td>21.1a</td>
<td>0.0b</td>
</tr>
<tr>
<td>1</td>
<td>A</td>
<td>4.8a</td>
<td>3.2b</td>
<td>0.24a</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>5.4a</td>
<td>2.6b</td>
<td>0.26a</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>4.8a</td>
<td>2.6b</td>
<td>0.27a</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>5.4a</td>
<td>2.6b</td>
<td>0.28a</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
<td>4.8a</td>
<td>3.2b</td>
<td>0.07a</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>4.6a</td>
<td>3.8b</td>
<td>0.07a</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>4.6a</td>
<td>3.0b</td>
<td>0.07a</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>4.8a</td>
<td>3.0b</td>
<td>0.07a</td>
</tr>
<tr>
<td>3</td>
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<td>3.7b</td>
<td>0.08a</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>4.7a</td>
<td>4.3b</td>
<td>0.07a</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>4.7a</td>
<td>2.7b</td>
<td>0.07a</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>5.1a</td>
<td>3.4b</td>
<td>0.07a</td>
</tr>
<tr>
<td>4</td>
<td>A</td>
<td>4.9a</td>
<td>3.4b</td>
<td>0.08a</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>5.0a</td>
<td>3.8b</td>
<td>0.07a</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>4.9a</td>
<td>2.7b</td>
<td>0.07a</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>5.5a</td>
<td>3.7b</td>
<td>0.08a</td>
</tr>
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<td>A</td>
<td>4.2a</td>
<td>5.0b</td>
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<td>B</td>
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<td>4.9a</td>
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<td>0.09a</td>
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<tr>
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<td>A</td>
<td>4.0a</td>
<td>5.9b</td>
<td>0.07a</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>4.2a</td>
<td>5.1b</td>
<td>0.05a</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>4.2a</td>
<td>3.6b</td>
<td>0.05a</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>4.7a</td>
<td>4.1b</td>
<td>0.09a</td>
</tr>
</tbody>
</table>

Each value is the mean of 10 replicates comprising 5 kg each. Mean values with the same letters in the same column are not significantly different at 5% level by DMRT

Treatment:  
A = hands  
B = clusters  
C = hands wrapped in perforated LDPE bags  
D = clusters wrapped in LDPE bags
Table 3. Quality of ripe banana cv. Mas after 6 weeks of storage in modified atmosphere at 14 °C

<table>
<thead>
<tr>
<th>Treatment*</th>
<th>Peel colour</th>
<th>Pulp colour</th>
<th>Texture</th>
<th>Taste</th>
<th>Peeling characteristics</th>
<th>TSS* (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6.5a</td>
<td>5.6a</td>
<td>6.9a</td>
<td>6.9a</td>
<td>7.0a</td>
<td>25.6a</td>
</tr>
<tr>
<td>B</td>
<td>6.5a</td>
<td>6.1a</td>
<td>7.0a</td>
<td>7.0a</td>
<td>7.0a</td>
<td>25.0a</td>
</tr>
<tr>
<td>C</td>
<td>7.0a</td>
<td>5.8a</td>
<td>6.7a</td>
<td>7.0a</td>
<td>7.0a</td>
<td>24.8a</td>
</tr>
<tr>
<td>D</td>
<td>7.0a</td>
<td>5.9a</td>
<td>7.0a</td>
<td>7.0a</td>
<td>7.0a</td>
<td>25.8a</td>
</tr>
</tbody>
</table>

Each value is the mean of 10 replicates. Mean values with the same letters are not significantly different at 5% level by DMRT

*Mean TSS of ripe unstored fruit is 25.0%
ripening, can be minimized. Fruit sold in the form of clusters would also be more affordable to consumers who prefer to purchase fruit in smaller quantity.

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References

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