Modified Atmosphere during Storage of 'Khai' Bananas in Polyethylene Bags: Implications for Export and Nationwide Transportation

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Abstract
The changes in the atmosphere, during storage of 'Khai' bananas, in the polyethylene (PE) bags, with or without an ethylene absorbent, were investigated.

Carbon dioxide (CO₂) reached 6% at day 5 after storage without the ethylene absorbent. At this concentration, CO₂ caused brown heart (carbon dioxide injury) symptom in banana fruit ripened with calcium carbide at ambient temperature. In contrast, with the ethylene absorbent, lesser than 5% CO₂ accumulated throughout the experimental period. The ethylene concentration in PE bags without the ethylene absorbent increased to 1.1 ppm at day 2 after storage. However, that in PE bags plus the ethylene absorbent, remained below 0.5 ppm. Soluble solids content of ripened banana that had been stored in PE bags without the ethylene absorbent (control fruit) was lower when compared with those of banana that had been stored in PE bags including the ethylene absorbent. The pulp of control fruits was firmer than those that had been stored in PE bags with the ethylene absorbent.

1. Introduction
Banana is one of the important tropical fruit crops grown commercially in Thailand. One of them is the 'Khai' variety. Its fruits have a pleasant flavor but their postharvest life is quite short due to sensitivity to ethylene. Scott and Roberts [1] reported that banana packed in polyethylene (PE) bags stayed firm and green for more weeks than control. In addition, development of carbon dioxide injury (brown heart) of those fruits kept in PE bags was also observed.

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Reducing the concentration of ethylene in the surrounding atmosphere of harvested crop commodities has been shown to delay the onset of senescence in non-climacteric produce and that of ripening in climacteric fruits [2] such as apple [3], avocado [4] and kiwifruit [5]. A very low level (0.1 ppm) of ethylene in atmosphere might enhance physiological activity of plant tissue. However, a wide range of other ethylene concentrations could have deleterious effect on fresh produce by decreasing postharvest life, which is linearly related to the increase of \( \log_{10} \) ethylene concentration [6-7].

Potassium permanganate (KMnO\(_4\)) has been used to remove low concentrations of ethylene in atmosphere around the produce. Since natural convection and diffusion are the only driving forces giving contact between ethylene and the oxidant, to be an effective ethylene absorbent, potassium permanganate needs to have a high surface area in contact with the atmosphere [8]. For this purpose, this compound can be incorporated onto inert carriers such as aluminium oxides, vermiculite, celite or calcium hydroxide.

The aim of this study was to investigate the concentrations of carbon dioxide and ethylene during storage of 'Khai' banana in closed atmospheres with or without the ethylene absorbent. With this information, the suitable conditions for export 'Khai' banana and nationwide transportation can be devised.

2. Materials and Methods

Mature green 'Khai' banana of uniform size was obtained from a local market in Bangkok. After de-handing, banana hands were dipped for 1 min in a solution containing 100 ppm chlorine and 500 ppm thiabendazole (TBZ), and were then dried with an electric fan at ambient temperature. Banana hands were randomly selected, weighed (3 kg/bag) and placed in sealed polyethylene (PE) bags (45x30 cm and 0.04 mm thickness) with or without potassium permanganate as the ethylene absorbent: 0 (control), 5 and 10 grams.

For preparation of the ethylene absorbent, calcium hydroxide pill (1.0 cm in diameter and 0.5 cm thickness) was submerging into a saturated potassium permanganate solution and then the pill was dried at room temperature. Five grams of soaked pills were packed in PE bags (each of 4x6 cm and 0.04 cm thickness) which had 5 holes (each of 0.5 cm in diameter) on both sides. All treatments were stored at 13°C (96% RH). The surrounding atmosphere inside the storage bag was withdrawn with GC-type syringe. Carbon dioxide and ethylene concentrations were measured using gas chromatography (GC) everyday. After storage, the hands were transferred to ambient condition and ripened with calcium carbide (15 g/1 kg) for 24 h. Content of soluble solids and flesh firmness were investigated using hand refractometer and Effegi penetrometer, respectively. All the experiments were replicated three times and each replicate consisted of 3 PE bags. Data obtained were analysed using Statistix for Windows (Analytical Software).

3. Results and Discussion

Banana is classified as a climacteric fruit. During ripening there is an increase in respiration rate (oxygen consumption and carbon dioxide release). Like other banana, 'Khai' variety has a short shelf life when stored at an ambient temperature [9]. At an initial stage, the composition of the surrounding atmosphere in a package of banana was about 21% O\(_2\), 0.03% CO\(_2\) and less than 0.01 ppm ethylene. Later, the level of CO\(_2\) increased sharply due to the climacteric rise in the respiration process (Figure 1). Carbon dioxide level reached 5 or 6% at day 4 and 5, respectively. The result also showed that 6% CO\(_2\) inside the sealed package enhanced CO\(_2\) injury (stayed hard and high amounts of starch) at the core part of banana fruit after ripening process was induced by calcium carbide. While CO\(_2\) accumulated inside the sealed package with the ethylene absorbent at both concentrations (5 and 10 grams), the level was higher in the package with 5 g of
the ethylene absorbent throughout the experimental period. However, the package plus 5 or 10 grams of the ethylene absorbent, the pulp firmness started to decrease at day 8 and 19 of storage, respectively. It seems that the ethylene absorbent could delay the respiration rate but did not affect the softening process [10]. Since, the concentration of ethylene in the sealed PE bags of banana without the ethylene absorbent increased from 0.8 to 1.1 ppm after 2 days of storage (Figure 2). This ethylene concentration can induce or be associated with the physiological activity of several plant tissues [2]. In the package with 5 grams of the ethylene absorbent, the initial ethylene concentration remained at about 0.5 ppm before decreasing to 0.25 ppm at day 3 of storage. This suggests that the capacity of ethylene absorbent was limited by the available contact surface [8]. While in the package with 10 grams of the ethylene absorbent, the initial level of ethylene remained at around 0.05 ppm until day 10 and then rose to 0.6 ppm. This indicated that 10 grams of the ethylene absorbent in the sealed bag were more efficient in removing ethylene than 5 grams of the ethylene absorbent in the first 10 days of storage.

Figure 2. Ethylene concentrations in sealed polyethylene (PE) bags containing 'Khai' bananas and the ethylene absorbent during storage at 13°C.

Modified atmosphere in PE bags with or without the ethylene absorbent has an influence on the quality of stored 'Khai' banana (Table 1). Banana in PE bags without the ethylene absorbent (control fruit) had poor fruit quality after storage. The fruit ripening process was incomplete as the content of soluble solids in the pulp of control fruit was low (about 18%) compared with that of banana stored in PE bags including the ethylene absorbent (about 24-26%). While the pulp firmness of control fruit remained at a higher level (2.8 Newtons) than that of banana stored in PE bags plus 5 or 10 grams of the ethylene absorbent (about 2.5 and 2.35 Newtons, respectively). This indicates that the ripening process of control fruit was affected by high concentrations of CO₂. Conversion of the starch content into sugars was likely to be impaired in control fruit. This CO₂ dioxide injury was not found in banana fruit stored in PE bags with the ethylene absorbent (Figure 1). However, quality of the long-term stored banana is not really better because it seems to lack of some ripening enzymes [11].

Figure 1. Carbon dioxide concentrations in sealed polyethylene (PE) bags containing 'Khai' bananas and the ethylene absorbent during storage at 13°C.

Though the quality of banana fruit packed with 5 and 10 grams of the ethylene absorbent was within the acceptable standard, there was some important
difference. The storage life of banana kept in PE bags including 10 g of the ethylene absorbent was more than double that in 5 grams of the ethylene absorbent after the banana was transferred to an ambient room and ripened with calcium carbide (Table 1). Therefore, we propose, from our experimental results that the suitable packaging conditions for export ‘Khai’ banana are storage with 10 grams of the ethylene absorbent and at 13°C. Package with 5 grams of the ethylene absorbent and storage at 13°C would be more suitable for nationwide transportation.

Table 1 Soluble solids and flesh firmness of ‘Khai’ bananas in sealed PE bags containing various levels of ethylene absorbent during storage at 13°C. Data are means from 3 replications ± SE

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Days in Storage</th>
<th>Soluble Solids (%)</th>
<th>Firmness (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>5</td>
<td>18.2±0.7</td>
<td>2.80±0.5</td>
</tr>
<tr>
<td>KMnO₄ (5 g)</td>
<td>8</td>
<td>26.3±1.1</td>
<td>2.5±0.7</td>
</tr>
<tr>
<td>KMnO₄ (10 g)</td>
<td>18</td>
<td>24.5±0.8</td>
<td>2.35±0.4</td>
</tr>
</tbody>
</table>

* Then transferred to ambient atmosphere and ripened with calcium carbide for 24 hr

References