MODIFIED ATMOSPHERE PACKAGING (MAP) OF MANGO AND AVOCADO FRUIT

Gustavo Gonzalez, Elhadi M. Yahia and Inocencio Higuera
Centro de Investigacion en Alimentacion y Desarrollo, A.C.
Apartado Postal 1735
Hermosillo, Sonora, Mexico

Abstract

Mango fruit (cv. Keitt) were individually packaged in low and high density polyethylene films (LDPE and HDPE) and kept at 20°C and 67% RH for 4 weeks. Characteristics of the films were determined. In-package O₂ and CO₂ were analyzed twice every week, and were found to be comparable to predicted atmospheres in LDPE but lower than predicted in HDPE. Fruits were evaluated objectively and subjectively every week for quality changes. MAP delayed fruit ripening, reduced weight losses, and did not result in any off-flavors. Avocado fruits (cv. Hass) were individually sealed in 5 films (4 LDPE and one HDPE) of different characteristics and kept at 5°C and 85% RH for 4 weeks. Three MAP treatments were used: one passive and two semi-active treatments. In semi-active MAP, CO₂ or CO₂ and N₂ were introduced to the package immediately after sealing. Atmosphere changes were analyzed at intervals, and fruit were evaluated every week for texture changes, weight losses, and for development of chilling injury. Texture and weight losses were reduced by MAP and were least in thicker films. Initial atmosphere modification, although reduced the accumulation of C₂H₄ in the packages, did not result in any additional benefits in regard to fruit texture and weight losses.

1. Introduction

Mexico is the biggest producer of avocado in the world, and the third biggest producer of mango after India and Brazil. The country produced 637,326 tons of avocado and 1,122,158 tons of mango in the 1987 season. Only about 1% of the avocado produced is exported. This is due to 3 factors: 1) The existence of a very strong internal market with the largest per capita consumption in the world (exceeds 8 Kgs), 2) Avocado is not exported to the USA due to quarantine, tariff, and other barriers, and 3) Mexico is far from other important markets such as Europe and Japan which are supplied by closer producers. The USA is traditionally the biggest market for Mexican mangos. In 1987, 42,614 tons have been supplied to this market (Anon, 1988). This quantity was reduced by about 50% in the 1988 season due the introduction of hot water treatment (46°C for 90 min) as an alternative to ethylene dibromide fumigation. More hot water treatment installations are being built in packinghouses for mango intended for export. However, The cost of installation is high and significant losses are noticed due to overripening.

Modified atmosphere packaging (MAP) is a technique which creates and
maintains a modified atmosphere around the commodity through the use of flexible film packages (Ben-Yehoshua 1985, Zagory and Kader 1988). MAP, when used properly and combined with other basic postharvest techniques such as cooling, can extend the storage life of several horticultural crops and reduces their quality losses (Kader et al., 1989).

Extensive efforts are being devoted to increase the export of such fresh horticultural crops due to the increase in world demand and the necessity of the Mexican economy for foreign currency. However, work is still needed to improve the postharvest handling systems for such perishable crops to reduce their losses and to permit their export, especially to farther markets, in an acceptable quality. The present study reports on the effect of MAP on the storage life and quality of mango and avocado.

2. Materials, methods, experiments

2.1.1. Materials, experiments

2.1.1. Mango

Mature, uniform mango fruit (Mangifera indica, cv. keitt) were harvested on July 1988 from the south of the state of Sonora, and transported within 5 hours to the laboratory at Hermosillo. At the same day, fruit were sorted again for color and size uniformity and for absence of defects. On the next day, 10 fruits were used to measure the respiration rate, 60 fruits were used for quality evaluation, and single fruits were sealed in high and low density polyethylene (LDPE and HDPE) bags (Table 1). Wrapped fruits were held at 20°C and 67% RH for up to 4 weeks. The contents of O₂ and CO₂ in the packages were analyzed twice every week. Fruit samples were evaluated once every week for flesh firmness, total soluble solids (TSS), titratable acidity (TA), and pH, and a sensory evaluation test was conducted for these fruits.

2.1.2. Avocado

Mature avocado fruit (Persea americana Mill, cv. Hass) were received in the laboratory from the state of Michoacan after 4 days from harvest. Upon arrival, fruits were sorted for uniformity and absence of defects, washed with chlorinated (200 ppm) water at ambient temperature and dried. Single fruits were then sealed in LDPE and HDPE bags (Table 1) and stored at 5°C and 85% RH for up to 4 weeks. Three MAP systems were used: 1) Passive system, where no gases were introduced to the package, 2) Semi-active system-1, where 100 ml of CO₂ were introduced to each package immediately after sealing, and 3) Semi-active system-2, where 100 ml of CO₂ and 200 ml of N₂ were introduced to the package immediately after sealing. Gases were introduced to the packages from compressed gas cylinders at predetermined constant flow. In-package O₂, CO₂ and C₂H₄ concentrations were measured at close intervals. Fruits (8 fruits/treatment) were evaluated every week for flesh firmness immediately after removal from MAP, and for development of chilling injury after holding for 2 days in air at 20°C.
2.2. Methods

2.2.1. Measurements of films characteristics
Digital micrometer (Model DDT, E.J. Cady and CO., Wheeling, IL) with a range of 0 to 1.25 mm was used to measure film thickness. Water vapour permeability was determined according to the method of ASTM. Oxygen permeability was measured by the use of an OX-TRAN 100A (Mocon, Modern Controls Inc., Minneapolis, Minn.).

2.2.2. Analysis of gases
Respiration rate (ml CO₂/Kg.hr.) was measured for single fruits exposed to a continuous flow of ethylene free air at 200 ml/min, using an infra red CO₂ analyzer (Horiba PIR 700). In-package CO₂ content was analyzed using the same instrument. Oxygen content in the package was measured using a portable O₂ analyzer (Mocon LC 700F). The accumulation of C₄H₄ in the package was analyzed using a HATCH CARLE series 400 gas chromatograph with an FID detector.

2.2.3. Objective quality evaluation measurements
Flesh firmness was determined on 6 points of each fruit using a firmness tester (Chatillon DFG 50, John Chatillon & Sons, Inc., New York, N.Y.) with 8 mm tip and skin removed. TSS was determined using a temperature adjusted refractometer, TA (as % citric acid) using 0.1 M NaOH, and pH using a pH meter.

2.2.4. Sensory evaluation
A balanced incomplete block design (BIB) was used for sensory evaluation (t=7, b=7, k=4, r=4, =2, E=0.88). Panelists were asked to detect the presence of any off flavors and to compare the treatments, using a hedonic scale, for aroma, taste, texture, skin and pulp color, and overall acceptability.

2.2.5. Chilling injury (CI)
CI, as a general gray discoloration in the mesocarp, was assessed according to the following scoring system; 0= no symptoms, 1=very slight, 2=slight, 3=moderate, 4=severe, 5=very severe.

3. Results

3.1. Mango
The respiration rate of mango (Fig. 1) indicated that fruits used in this experiment were at the initial stage of ripening. Their respiration rate increased and reached a peak after 3 days in air at 20°C. Fruits sealed in HDPE for one week and then exposed to air had a high respiration and reached a peak within 4 days, while those sealed in LDPE had a low respiration and reached a peak after 10 days in air. Fruits sealed in LDPE and HDPE for 2 weeks and then exposed to air had a low respiration rate, which increased and reached a peak after 6 days for HDPE and 8 days for LDPE.
The In-package O₃ concentration (Fig. 2) dropped very fast in both types of polyethylene bags and reached 8 to 10% within 2 days. It was relatively stable thereafter in LDPE, but started to increase after 2 weeks in HDPE until it reach about 14% at the end of storage period. In-package CO₂ concentration was 3% in HDPE and 7% in LDPE after 2 days of storage, reached a maximum of 8% and 10% in HDPE and LDPE, respectively, after 10 days of storage. The CO₂ content in the packages was then decreased and reached 3% and 5% in HDPE and LDPE, respectively. In-package O₂ and CO₂ levels were compared to predicted values using analytical equations (Deily and Rizvi, 1981). Predicted in-package CO₂ and O₂ were comparable with those obtained experimentally in LDPE but were lower for HDPE.

MAP resulted in a substantial reduction in fruit weight loss compared to non-sealed fruits but did not result in significant differences in flesh firmness, TSS, TA, or pH. Only minor decay incidences were observed in fruits stored for 4 weeks, and were higher in fruits wrapped in HDPE.

Sensory evaluation tests (data not shown) did not reveal the presence of any off-flavors. Fruit overall acceptability was low for the first week, increased in the second and third week and decreased in the fourth week. A hedonic scale of 0 to 5 was used to evaluate overall acceptability where 0=dislike very much, 3=like, and 5=like very much. Fruits stored for one week received an average score of 2 to 3. Panelists rated these fruits slightly low in taste, low in aroma, and with a firm texture. Fruits stored for 2 and 3 weeks received an average score of 3 to 4, were rated higher in taste and aroma and had less firm texture than those stored in MAP for one week. Fruits stored for 4 weeks had an average overall acceptability score of 2.5 to 3. These scores, although lower, are not significantly different from those for fruits stored for 2 and 3 weeks. Aroma, taste, and firmness scores for these fruits were comparable to those for fruits stored for 2 and 3 weeks. No significant differences in all sensory characteristics were observed either between sealed and non-sealed fruits or between fruits sealed in the 2 different films.

3.2. Avocado

LDPE films used ranged in thickness from 0.015 to 0.066 mm, and their permeabilities ranged from 111 to 605 cc O₂/m².hr.atm, and 0.167 to 0.246 gm H₂O/m².hr.atm. The HDPE film used had the least thickness and the highest O₂ permeability (Table 1).

In-package O₂ concentration in the passive MAP (Fig. 4A) after 2 days was <5% in LDPE-1, 7.5% in LDPE-2, 13% in LDPE-3, 12% in LDPE-4, and 18.5% in HDPE. It decreased further (except in LDPE-1) and increased after one week. It became stable after about 2 weeks at about 10% in LDPE-1, 11% in LDPE-2, 14% in LDPE-3, 16% in LDPE-4 and 17.5% in HDPE. In-package CO₂ contents (Fig. 4A) were highest in LDPE-1 and LDPE-2 (Ca 8%) and lowest in LDPE-4 and HDPE (Ca 2-3%) after 2 days in storage. LDPE-3 had an intermediate CO₂ content of about 5%. The introduction of 100 ml N₂ or 100 ml CO₂ and 200 ml N₂ to the package (Fig. 4B & C) resulted in less
variability in the initial atmosphere and reduced the O₂ and increased the CO₂ in this atmosphere. The introduction of 100 ml CO₂ to the package (Fig. 4B) maintained an atmosphere with ≤15% O₂, except in LDPE-4 and HDPE after 3 weeks. It initiated an atmosphere with very high CO₂ content (18-23%), but continuously decreased and was maintained at about 7% for LDPE-1 and LDPE-2, 5% in LDPE-3, 3.5 in LDPE-4, and 2.5% in HDPE, after 2 weeks. The introduction of 100 ml CO₂ and 200 ml N₂ to the packages (Fig. 4C) initiated an atmosphere with low O₂ (3.5-5%) and high CO₂ (16.5%-20%). In package-O₂ contents increased steadily and was about 12% in LDPE-1, 13% in LDPE-2, 14.5% in LDPE-3, 16% in LDPE-4, and 17% in HDPE after 2 weeks. In package-CO₂ decreased steadily and was established after 2 weeks at about 8% in LDPE-1, 6% in LDPE-2, 5% in LDPE-3, 4% in LDPE, and 3% in HDPE.

In package ethylene accumulation (Fig. 4) was highest at the beginning and declined to about 1 to 3 ppm after 2 weeks. In the passive MAP, ethylene accumulation was highest as the thickness of the films increased. The initial modification of the atmosphere in the bags reduced the accumulation of ethylene.

MAP resulted in significant reduction in fruit weight losses (Fig. 5). Reduction in the losses of fruit firmness was only observed in films with more than 0.03 mm thickness. The introduction of either CO₂ or CO₂ and N₂ did not result in any further reduction in the losses of fruit firmness and weight.

CI development (data not shown) was very low in the control and MAP fruit. CI development of MAP fruit was much lower than the control except for LDPE-3, LDPE-4, and HDPE after 4 weeks of storage.

4. Discussion

MAP in LDPE and HDPE was effective in reducing weight losses in mango but did not result in significant improvement in any other quality characteristic. Organoleptic evaluation did not reveal the presence of any off-flavors. Previous results of MAP mango are not consistent. Eguerra et al. (1978), using 0.08 mm thick bags, stored mangos for 3 weeks at 10°C and found that fruit ripened with ethylene to normal color, texture, and flavor. However, Chaplin et al. (1982), using uncharacterized polyethylene bags, and Miller et al. (1986), using characterized films, did not recommend the technique of film wrapping of mango due to the development of off-flavors. Mangos do not seem to benefit very easily by wrapping in flexible films. However, due to the recent advances in the manufacturing and characterization of polymeric films, further studies should be conducted to optimize a MAP system for this fruit.

On the other hand, MAP was reported to extend the postharvest life and reduce CI in avocado (Chaplin and Hawson 1981, Oudit and Scott 1973, Scott and Chaplin 1978). Results reported in this paper indicate that MAP avocado had the least texture and weight losses compared to non-wrapped fruits. Films with the most thickness maintained an atmosphere with the lowest O₂ and
highest CO₂ and resulted in the least losses in fruit firmness and weight. Initial modification of the atmosphere by introducing CO₂ and N₂ to the packages, although reduced the accumulation of C₂H₄, did not result in any additional benefits due to the short period in which the initially modified atmosphere was maintained. Further studies should be conducted using films with less permeabilities that can maintain an initially modified atmosphere for periods sufficient to delay ripening.

5. Acknowledgements
The authors are grateful to M. Romo, O. Hernandez, and A.M. Mendoza for their assistance.

6. References
Table 1: Characteristics of the films used for packaging of mango and avocado.

<table>
<thead>
<tr>
<th>Film</th>
<th>Thickness (mm)</th>
<th>Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>O₂ (cc/m².hr.atm.)</td>
</tr>
<tr>
<td>A-mango</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDPE*</td>
<td>0.010</td>
<td>700</td>
</tr>
<tr>
<td>HDPE</td>
<td>0.020</td>
<td>800</td>
</tr>
<tr>
<td>B-Avocado</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LDPE-1</td>
<td>0.066</td>
<td>111</td>
</tr>
<tr>
<td>LDPE-2</td>
<td>0.043</td>
<td>225</td>
</tr>
<tr>
<td>LDPE-3</td>
<td>0.028</td>
<td>416</td>
</tr>
<tr>
<td>LDPE-4</td>
<td>0.015</td>
<td>605</td>
</tr>
<tr>
<td>HDPE</td>
<td>0.013</td>
<td>631</td>
</tr>
</tbody>
</table>

* LDPE=low density polyethylene, HDPE=High density, polyethylene. Bags volume were 750 ml for mango and 700 ml for avocado.

Fig. 1. Respiration rate of mango. A- immediately after harvest, B- after one week in MAP, and C- after two weeks in MAP. Control, —— LDPE, ——— HDPE.
Fig. 2. Predicted (----) and experimental (-----) in-package O₂ and CO₂ respectively, of MAP mango at 20°C.

Fig. 3. Firmness(N), % weight loss, pH, % TSS, and % TA of MAP mangos stored for 4 weeks at 20°C.
- Control, ----LDPE, -----HDPE.
Fig. 4. In-package O₂, CO₂ and C₂H₄ contents of MAP avocado. A= passive, B= Semi-active-1, and C= Semi-active-2. -- LDPE-1, -- LDPE-2 --LDPE-3, --LDPE-4, -- HDPE.
Fig. 5. Firmness (N) and % weight loss of MAP avocado stored for 4 weeks at 5°C.

- LDPE-1
- LDPE-2
- LDPE-3
- LDPE-4
- HDPE
- Control