during the curing period before cold treatment. Film wraps may help reduce chilling injury of grapefruit (10) which often occurs at the low temperatures used for cold sterilization.

Experimental machinery for shrink film wrapping of citrus has been tested in Florida the last 3 or 4 yr. The first machine tested was a Shanklin (100 Westford Rd., Ayer, MA 01432) horizontal automatic-fill L sealer. This was modified to run 2 rows of fruit and could run 60 to 80 fruit/min. No further developments have occurred with this machine. Weldotron (1582 S. Washington Ave., Piscataway, NJ 08854) and Cryovac (P.O. Box 464, Duncan, SC 29384) are testing horizontal and vertical form-fill wrapping machines, respectively. These single line machines wrap approximately 60 fruit/min. The Doboy Packaging Machinery Corp. (New Richmond, WI 54017) is testing a fruit wrapping machine in the western U.S.A. and stretch-film fruit wrapping machinery has been tested in Italy. Some horizontal form-fill machines in Japan can wrap small, uniformly shaped objects at the rate of 250 units/min. Faster wrapping rates such as these or multiple line machines will be needed to provide adequate wrapping rates for commercial citrus wrapping.

Some preliminary consumer acceptance evaluation has taken place (DuPont Corp. and Seal Sweet, unpublished). On the negative side, many consumers were concerned about how much more wrapped fruit would cost. On the plus side, consumers in the U.S. and Europe perceive the wrapped fruit to be more sanitary. Little consumer education about the advantages of film wrapped citrus has been done but will be required to promote wrapped fruit. Cryovac recently started an advertising campaign for wrapped citrus.

Major uses for film wrapping in marketing fresh citrus appear to be in export marketing where extended holding times are required and for long-term storage to allow extensive summer sale of grapefruit and oranges. If decay can be controlled, film wrapping would allow early to mid-April harvest of grapefruit for storage, thereby avoiding most seed sprouting and section drying problems (2, 3).

Some gift fruit shippers are interested in film wrapping because of the quality appearance, labeling potential, and containment of decay soilage. Another possible place for film wrap use could be to extend the marketing period of some mandarin varieties until the next variety is mature. For an early variety such as 'Robinson,' this could include cool coloring while storing to avoid degreening. This early harvest procedure would avoid the poor internal quality (section drying) associated with later harvests of most mandarin varieties. All the possible uses of film-wrapping will require better handling and more consistent decay control than presently occurs in the Florida fresh citrus industry.

**Literature Cited**


**Abstract.** The use of polymeric films in produce packaging has recently increased due to the development of new films. Broccoli (Brassica oleracea L. Italica group) and cucumber (Cucumis sativus L.) were individually seal-packaged in unperforated or perforated polyethylene films of 0.01 or 0.02 mm thickness. Storage temperatures were 1, 7.5, and 15°C for broccoli and 1, 10, and 20°C for cucumber. After 2 wk in storage weight loss of seal-packaged, perforated, and unwrapped broccoli was 1.1, 22.4, and 35.8%, respectively.

Seal-packaged cucumber stored at 20°C lost 5% of its initial weight after 5 wk in storage, whereas perforated and unwrapped treatments lost up to 85%. Vegetables stored in perforated films maintained their fresh appearance and firmness more than 4 times as long as those which were conventionally handled. Film thickness had no effect on weight loss.


**DELAYING DETERIORATION OF BROCCOLI AND CUCUMBER USING POLYMERIC FILMS**

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Additional index words. Brassica oleraces L. Italica group, Cucumis sativus, high-density polyethylene film, weight loss.
but it significantly affected in-package CO₂ and O₂ concentrations. Taste panel tests with broccoli did not reveal significant differences between unperforated and perforated film treatments.

Postharvest losses of produce usually range from 15 to 25% or more (13). Among the methods used to reduce these losses are cooling, waxing, and packaging. Refrigeration is the most important means of extending produce shelf-life, but it is costly and not economically feasible for all perishables. The use of polymeric films has gained importance in this respect because of its convenience and low cost (1, 2). Packaged produce is a dynamic system in which respiration and permeation are occurring simultaneously. Selection of the proper film type and thickness could reduce water loss and favorably modify the in-package atmosphere, thereby extending the produce shelf-life (9, 17). During the early 1940’s, Stahl et al. (16) tested the effectiveness of various film wraps in extending the storage life of many fruits and vegetables and obtained encouraging results.

Most of the recent work on film packaging has been performed with citrus fruit (1, 2, 3, 11, 12, 14, 18). Seal packaging of oranges and lemons (2, 3) in 0.01 mm thick polyethylene films reduced weight loss by 5-fold as compared to unwrapped fruit. Sealed fruits held at 20°C were firmer and lost less weight than non-sealed fruit at 10°C. Likewise, Ben-Yehoshua et al. (4) reported similar findings with lemon and pepper. They suggested that the mode of action of seal packaging in extending shelf-life was related to the alleviation of water stress which existed in harvested fruits.

Results with grapefruit (11) individually sealed in polyethylene (0.015 mm) indicated that weight loss was reduced by 58 to 84%. Film packaging also extended the postharvest life of apples (7), and facilitated the shipment of grapefruit (12) and avocados (5) without refrigeration or humidity control.

Most of the research on vegetable packaging was done during the 1940’s (6, 15, 16). Since then, very limited work had been done in this field possibly due to the lack of films with appropriate permeation characteristics. With the recent development of new films and packaging techniques, promising results could possibly be obtained with a variety of vegetables (4, 9, 10).

This study tests the effectiveness of selected polymeric films in extending the postharvest life of broccoli and cucumber stored at different temperatures.

Materials and Methods

Broccoli and cucumber were harvested from research plots near Gainesville, Florida in the fall of 1982. Broccoli heads and European cucumbers of uniform sizes and stages of maturity were selected and prepared for storage immediately after harvest. The packaging films used in this study were Clysar EHC-50 gauge (0.01 mm) and EHC-100 gauge (0.02 mm), made by DuPont. Storage bags of 25 x 30 cm were made from these films using a Cryovac Magna-Lok Edgeseal machine (Cryovac Division, W. R. Grace & Co., Duncan, S.C.).

Broccoli and cucumber were sealed in intact or perforated bags (48-6 mm perforations) using a Counter Craft Seal-N-Save sealing bar (Sears, Roebuck and Co., Chicago, IL). The non-perforated bags were provided with rubber septa by applying silicone rubber caulking. The control treatments were left unpackaged. The vegetables were numbered, weighed, and placed in storage rooms at 1, 7.5, or 15°C for broccoli, and 1, 10, or 20°C for cucumber. Relative humidity of storage rooms ranged from 65 to 75%. The experimental design was a randomized complete block design. Treatments consisted of a 5 x 3 factorial arrangement with 5 replications for broccoli and 4 for cucumber. Vegetables were weighed at weekly intervals and weight loss was calculated as percent weight loss from the initial weight.

Air samples for CO₂, O₂, and C₂H₄ determinations were drawn from non-perforated bags by syringes through rubber septa at weekly intervals. Carbon dioxide and O₂ were determined using a Fisher-Hamilton Gas Partitioner, Model 29, and C₂H₄ was determined using a Hewlett-Packard 5710A gas chromatograph.

A triangle taste difference test was performed for broccoli by experienced evaluators. In the spring of 1983, a second broccoli packaging experiment was conducted according to the above described procedure.

Results and Discussion

Effects on weight loss. Sealing broccoli in polyethylene films of both thicknesses significantly reduced weight loss in both experiments (Fig. 1, 2). Weight loss from sealed, perforated, and unwrapped treatments was 1.2, 14.5, and 26.3%, respectively, for the first experiment (Fig. 1), and 1.0, 23.2, and 45.6%, respectively, for the second experiment (Fig. 2) after 2 wk in storage at 15°C. Hence, reduction in weight loss obtained with seal-packaging over the control was 95 and 98% for the first and second experiments, respectively. Similar results were reported by Kawada and Albrigo (11) for grapefruit. They reported a reduction in weight loss of grapefruit sealed in 0.015 mm polyvinylchloride and polyethylene films of 58 and 84%, respectively. We found no significant difference in weight loss could be attributed to film thickness. Sealed broccoli heads maintained their initial color and firmness longer while perforated and unwrapped treatments shriveled and displayed signs of senescence (yellowing). In both experiments, perforated and unwrapped treatments showed a steady increase in weight loss as temperature increased (Fig. 1, 2). However, with the sealed treatments, an increase in temperature was not accompanied by an appreciable increase in weight loss. This is probably due to the moisture-saturated atmosphere maintained in the

[Graph: Fig. 1. Effects of film wrap treatments and temperature on % weight loss of broccoli (1st expt.) after 2 wk in storage. V = unwrapped control, ▲ = EHC-100 (perforated), ■ = EHC-50 (perforated), □ = EHC-100 (unperforated), ○ = EHC-50 (unperforated).]
sealed packages. Although seal-packaging minimized weight loss even at the highest temperature tested, it did not prevent yellowing and deterioration of broccoli at higher (non-optimal) temperatures where the produce was not marketable after 1 wk in storage. This might be due to the higher concentrations of ethylene accumulated at the medium and higher temperatures (Table 1). Seal-packaged broccoli heads stored at 1°C maintained their fresh appearance and quality more than 4 times longer than the perforated and unwrapped treatments. Even at optimal storage temperatures, seal-packaging can be of great benefit in maintaining quality of perishables.

Table 1. Interactions of film wrapping and temperature on ethylene concentration after 2 wk in storage. Second broccoli experiment.

<table>
<thead>
<tr>
<th>Film wrap</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ethylene ppm</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>15</td>
</tr>
<tr>
<td>Perforated</td>
<td>Tr</td>
</tr>
<tr>
<td>Unperforated</td>
<td>0.69*</td>
</tr>
<tr>
<td>Perforated</td>
<td>Tr</td>
</tr>
<tr>
<td>Unperforated</td>
<td>2.17</td>
</tr>
<tr>
<td>Perforated</td>
<td>Tr</td>
</tr>
<tr>
<td>Unperforated</td>
<td>1.97</td>
</tr>
</tbody>
</table>

Orthogonal comparisons for the interaction of quadratic temperature effects and film wrapping (perforated vs. unperforated) significant at P = 0.001.

Similar effects of seal-packaging were obtained with cucumber (Fig. 3). Seal-packaged cucumber treatments at 20°C lost 5% of their initial weight after 5 wk in storage, whereas perforated and unwrapped treatments lost up to 85%. Seal-packaged cucumbers stored at 10 and 20°C maintained their texture and color at least 6 times as long as the perforated and unwrapped treatments.

As storage temperatures increased, weight loss of seal-packaged fruits also increased (Fig. 3). However, weight loss of seal-packaged fruit, even at 20°C, was negligible compared to the weight loss of perforated and unwrapped fruit.

Table 2. Interactions of film wrapping and temperature on CO₂ concentration after 2 wk in storage. Second broccoli experiment.

<table>
<thead>
<tr>
<th>Film wrap</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CO₂ (%)</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>15</td>
</tr>
<tr>
<td>Perforated</td>
<td>0.05*</td>
</tr>
<tr>
<td>Unperforated</td>
<td>0.04</td>
</tr>
<tr>
<td>EHC-50</td>
<td>3.66</td>
</tr>
<tr>
<td>EHC-100</td>
<td>3.79</td>
</tr>
<tr>
<td>EHC-50</td>
<td>3.79</td>
</tr>
</tbody>
</table>

Orthogonal comparisons for the interaction of temperature effects and film thickness were also significant at P = 0.001.

Effects on in-package atmospheres. Film wrap treatments significantly interacted with temperature in their effects on in-package gaseous composition of broccoli after 15 days in storage (Tables 2, 3, 4). Carbon dioxide evolution and O₂ consumption increased linearly as temperature increased from 1 to 15°C. Film thickness significantly influenced CO₂ and O₂ concentrations (Tables 2, 3). Apparently, EHC-50 film (0.01 mm) maintained lower CO₂ and higher O₂ levels than EHC-100 film (0.02 mm) and therefore seemed to be more suited for vegetable packaging and storage. However, even with the thicker film (EHC-100) and at the highest temperature tested, no harmful concentrations of CO₂ were
Table 3. Effects of film wrapping on O₂ concentration after 2 wk in storage. First broccoli experiment.

<table>
<thead>
<tr>
<th>Film wrap</th>
<th>O₂ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unwrapped</td>
<td>20.0*</td>
</tr>
<tr>
<td>Film wrap</td>
<td>14.2</td>
</tr>
<tr>
<td>EHC-50</td>
<td>15.0</td>
</tr>
<tr>
<td>EHC-100</td>
<td>13.3</td>
</tr>
</tbody>
</table>

Table 4. Interactions of film wrapping and temperature on O₂ concentration after 2 wk in storage. First broccoli experiment.

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Unperforated</th>
<th>Perforated</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11.7*</td>
<td>20.0</td>
</tr>
<tr>
<td>7.5</td>
<td>6.5</td>
<td>20.0</td>
</tr>
<tr>
<td>15</td>
<td>6.9</td>
<td>20.0</td>
</tr>
</tbody>
</table>

Orthogonal comparisons of film wrapping treatments significant at P = 0.0001.

Orthogonal comparisons for the interaction of temperature effects and film wrapping (perforated vs. unperforated) significant at P = 0.01.


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CONTROL OF FLORIDA CITRUS DECAYS WITH GUAZATINE

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Abstract. Guazatine (Panocine) (1, 17-diguanidino-9-azaheptadecane acetate) is a postharvest fungicide which, unlike the currently registered materials, is effective against sour rot caused by Geotrichum candidum Lk. ex Pers. Efforts are there-