

EFFECTS OF FILM WRAPPING ON MATURE-GREEN TOMATOES BEFORE AND AFTER ETHYLENE TREATMENT¹

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Abstract. In 3 separate tests, Florida mature-green tomatoes were film wrapped in 2 types of film before and after ethylene treatment. Tomatoes were stored at 15.6°C for 1 or 2 weeks and an additional 3 and 7 days at 21°C, evaluated for weight loss, color, decay, and firmness. Gas composition of film-wrapped tomatoes was also measured during ethylene treatment and storage. Generally, film wrapping tomatoes before ethylene treatment slowed color development, reduced weight loss, and maintained firmness compared to wrapping after ethylene treatment. Gas composition surrounding the tomato was related to the gas diffusion characteristics of the film, and gas production/consumption rate of the tomato. Decay development was about the same for tomatoes film wrapped before or after ethylene treatment.

Florida is the largest producer of fresh-market tomatoes, and for many years shippers and receivers have been interested in extending the shelf life of tomatoes. Generally, Florida producers harvest their tomatoes during the mature-green stage and then treat them with ethylene for initiation of the ripening process. Consumers of tomatoes prefer firm and fully-red tomatoes (8). Recommendations for the transit and storage of ethylene-treated (ET), mature-green tomatoes specify that temperatures be maintained at 12.8 to 21°C, and for ripe tomatoes at 7.2 to 10°C (6).

Film wrapping of fresh fruits and vegetables has been studied by researchers and was summarized in a recent review (1). The main advantages of film wrapping are 1) reduced weight loss and extended shelf life, 2) minimized fruit deformation, 3) reduced chilling injury, and 4) reduced spread of infection from fruit to fruit packed in the same box. In some studies, the incidence of decay was increased by film wrapping. Several researchers (2, 3, 5, 7) have studied the packing of tomatoes either in polyethylene bags or individually wrapped in film. Mature-green tomatoes individually wrapped in heat-shrinkable plastic film after ET had less weight loss, were firmer, and developed less internal color than nonwrapped tomatoes stored for up to 3 weeks at 12.8°C and held an additional 7 days at 21°C (7). The objectives of this study were to determine the effects of film wrapping on mature-green tomatoes before and after ethylene treatment on ripening and shelf life.

Materials and Methods

Mature-green tomatoes (cultivar FTE-12) were obtained from a Dade County packinghouse. Three tests were conducted at ca. 5-week intervals starting in February 1984. Tomatoes (size 6 x 6) were brought to the Orlando USDA Laboratory immediately after washing (200 ppm chlorine),

grading, and packing. On arrival in Orlando, 45 mature-green tomatoes were selected at random for each of the following treatments:

1. control nonwrapped, then 3 days ET
2. wrapped EHC-50, then 3 days ET
3. wrapped LDPE, then 3 days ET
4. 3 days ET, then wrapped EHC-50
5. 3 days ET, then wrapped LDPE
6. 5 days ET, then wrapped EHC-50
7. 5 days ET, then wrapped LDPE
8. 5 days ET, then nonwrapped.

Ethylene treatment was accomplished by placing the tomatoes in a degreening room for the prescribed number of days with 50 ppm ethylene at 21°C. Two types of films were used in the study: 1) Clysar EHC-50® biaxially oriented, heat-shrinkable copolymer film of 0.5 mil nominal thickness, and 2) a low-density, polyethylene film (LDPE) of 0.6 mil thickness. Both films have relatively low water-vapor permeability and high gas permeability, with LDPE having a slightly higher water-vapor permeability and lower gas permeability than EHC-50.

The tomatoes were individually wrapped using a Weldomatic® sealer (Model 6001), and then conveyed through a Weldomatic® heat tunnel (Model 7001). Travel time through the tunnel was ca. 7 sec, at temperatures from ca. 163 to 177°C, resulting in a maximum tomato surface temperature of ca. 38°C.

Each treatment of 45 tomatoes was packed in the conventional 11.3 kg part-telescope, fiberboard box and placed in a 15.6°C room with 85-90% relative humidity for either 1 or 2 weeks. Following initial storage and after 3 or 7 days' holding at 21°C and 88-95% relative humidity, 15 tomatoes were removed from each box for evaluation. Weight loss, firmness, color and decay were recorded for each tomato. Both external and internal tomato color measurements were recorded with a Hunter® color difference meter (Model D25-9) signal processor using a white standard plate with values of L = 90.5, a = -1.4, and b = -1.7 with an optical sensor (Model D25-L). This instrument has been valuable in citrus and tomato studies, and a detailed account of the requirements for its use in reproducible measurement of tomato color has been published (4). Three external readings were made on each tomato by placing it over the viewing area of the color difference meter covering it with a black cup and rotating it at evenly spaced locations in its equatorial region. One internal color reading per tomato was taken by slicing the tomato in half transversely at the equator and placing the stem-end half over the viewing area of the color difference meter and covering with a black cup. An Instron® food-testing system (Model 1132) was used to measure firmness of the tomatoes by applying a load cell calibrated to a range of 0-10 kg at a constant speed of 5 cm/min by a 5.7 cm round anvil to the tomato surface and recording the amount of force required to depress the surface of the tomato 5 mm. The incidence and types of decay were determined at each inspection.

At ca. 3-day intervals throughout the 2 weeks of storage at 15.6°C and 1 week at 21°C storage, gas samples were taken from 5 tomatoes by inserting a syringe through the film, generally near the stem end of the tomato, into a void air space between the film and the tomato to draw the gas sample. Gas samples were analyzed by gas chromatography.

¹Use of a company or product name by the U.S. Department of Agriculture does not imply approval or recommendation of the product to the exclusion of others which may also be suitable.

Results and Discussion

Weight loss was significantly reduced by wrapping tomatoes before ET during all storage periods compared to wrapping after ET for 3 or 5 days, or for nonwrapped tomatoes (Tables 1 and 2). Weight loss was significantly reduced by wrapping after ET for 3 days compared to wrapping after ET for 5 days except for tomatoes stored 2 weeks at 15.6°C plus 7 days at 21°C, or for nonwrapped tomatoes.

Firmness of the tomatoes was inversely related to weight loss. Generally, as weight loss of tomatoes increased, firmness decreased. In all storage treatments, except after 2 weeks' storage at 15.6°C plus 7 days at 21°C, firmness of wrapped tomatoes before ET in LDPE film was significantly more than the firmness of all other wrapped and nonwrapped tomatoes (Tables 1 and 2). Nonwrapped tomatoes ET for 5 days were the least firm for all storage periods, and during extended storage periods of 2 weeks at 15.6°C, plus 7 days at 21°C, some of these tomatoes were soft and overripe.

Generally, there were only slight differences in amount of decay between wrapped and nonwrapped tomatoes. After 1 or 2 weeks' storage at 15.6°C plus 7 days at 21°C, there was no difference in percentage of decay for all treatments. The amount of decay increased with storage time and during storage at 21°C. The 3 major types of decay in order of decreased incidence were bacterial soft rot, alternaria rot, and sour rot. Many tomatoes were rated as decayed, even though the decay (mostly alternaria rot) measured less than 1 cm in diameter.

Although the Hunter® color difference meter provides 3 values (L, a, b), there are several ways to express these data, but the procedure that has gained widespread acceptance for tomatoes is calculation of the a/b ratio (8).

Wrapping tomatoes before ET significantly reduced both external and internal color development expressed by a lower a/b value compared to wrapped tomatoes after ET and nonwrapped tomatoes for all storage treatments (Tables 1 and 2). In all storage periods, tomatoes wrapped in the LDPE film before ET had the least amount of external and internal color development, followed closely by tomatoes wrapped in the EHC-50 film before ET. Generally, the highest amount of color development was for nonwrapped tomatoes ET for 5 days; followed by tomatoes ET for 5 days then wrapped; and finally, by nonwrapped tomatoes ET for 3 days. After 2 weeks' storage at 15.6°C plus 7 days at 21°C, wrapped tomatoes ET for 3 days finally reached an acceptable color and were considered table ripe.

Lower concentrations of O₂ were found under the film of LDPE-wrapped tomatoes (18.9%) than under that of EHC-wrapped tomatoes (19.8%) during the 21-day storage period, but similar concentrations of CO₂ and C₂H₄ were found; however, more time was required for the CO₂ and C₂H₄ to build up in the LDPE- than in the EHC-wrapped tomatoes (Table 3). In the LDPE-wrapped tomatoes, about 3 days more were required for the C₂H₄ to build up compared to that in EHC-wrapped tomatoes, and resulted in the slower rate of ripening as evidenced by color development.

In general, mature-green tomatoes can be wrapped before ET and will ripen satisfactorily depending on the gas permeability of the film and the length of storage time. The rate of color development was slower, weight loss was less, and tomatoes firmer when wrapped before, rather than after, ET. Wrapping before ET may be a useful method to prolong quality and freshness of tomatoes during export shipment or extended storage.

Table 1. Weight loss, color, firmness and decay of nonwrapped and wrapped tomatoes before or after ethylene treatment and stored for 1 wk at 15.6°C^a and after 3 and 7 days at 21°C^a, means of 3 tests, 1984.

| Treatment | Weight loss (%) | Hunter® color | | Firmness (kg) | Decay (%) |
|---------------------------------|-----------------|----------------|----------------|---------------|-----------|
| | | External (a/b) | Internal (a/b) | | |
| 1 wk at 15.6°C | | | | | |
| Nonwrapped—3 days ET | 1.52 cv | 1.29 b | 1.03 ab | 3.12 cd | 2 a |
| Wrapped EHC-50—3 days ET | 0.26 e | 0.81 d | 0.75 c | 3.96 b | 4 a |
| Wrapped LDPE—3 days ET | 0.41 e | 0.57 e | 0.51 d | 4.31 a | 0 a |
| 3 days ET—wrapped EHC-50 | 1.18 d | 1.20 bc | 0.96 ab | 3.57 bc | 0 a |
| 3 days ET—wrapped LDPE | 1.17 d | 0.95 c | 0.85 bc | 3.67 bc | 2 a |
| 5 days ET—wrapped EHC-50 | 1.69 bc | 1.56 a | 1.08 a | 2.70 de | 2 a |
| 5 days ET—wrapped LDPE | 1.80 ab | 1.51 a | 1.10 a | 2.61 e | 0 a |
| Nonwrapped—5 days ET | 1.97 a | 1.51 a | 1.11 a | 2.46 e | 4 a |
| 1 wk at 15.6°C + 3 days at 21°C | | | | | |
| Nonwrapped—3 days ET | 2.12 b | 1.76 ab | 1.45 a | 2.00 c | 7 ab |
| Wrapped EHC-50—3 days ET | 0.40 d | 1.63 b | 1.30 b | 2.54 b | 0 a |
| Wrapped LDPE—3 days ET | 0.57 d | 1.21 c | 0.95 c | 3.16 a | 4 ab |
| 3 days ET—wrapped EHC-50 | 1.27 c | 1.77 ab | 1.38 ab | 2.39 bc | 11 b |
| 3 days ET—wrapped LDPE | 1.32 c | 1.64 b | 1.38 ab | 2.37 bc | 2 ab |
| 5 days ET—wrapped EHC-50 | 1.89 b | 1.95 a | 1.43 a | 2.05 c | 7 ab |
| 5 days ET—wrapped LDPE | 2.04 b | 1.90 a | 1.40 a | 2.08 c | 4 ab |
| Nonwrapped—5 days ET | 2.53 a | 1.94 a | 1.43 a | 1.99 c | 9 ab |
| 1 wk at 15.6°C + 7 days at 21°C | | | | | |
| Nonwrapped—3 days ET | 2.75 b | 2.00 bc | 1.53 a | 1.52 de | 9 a |
| Wrapped EHC-50—3 days ET | 0.60 e | 1.89 c | 1.46 ab | 1.93 b | 7 a |
| Wrapped LDPE—3 days ET | 0.69 e | 1.66 d | 1.37 b | 2.24 a | 7 a |
| 3 days ET—wrapped EHC-50 | 1.52 d | 2.06 abc | 1.55 a | 1.91 b | 4 a |
| 3 days ET—wrapped LDPE | 1.55 d | 1.98 bc | 1.53 a | 1.83 bc | 7 a |
| 5 days ET—wrapped EHC-50 | 2.00 c | 2.16 ab | 1.55 a | 1.65 cd | 4 a |
| 5 days ET—wrapped LDPE | 2.23 c | 2.20 a | 1.56 a | 1.68 cd | 9 a |
| Nonwrapped—5 days ET | 3.12 a | 2.06 ab | 1.57 a | 1.37 e | 11 a |

^aRelative humidity during 15.6°C storage was 85 to 90% and 88 to 95% during 21°C storage.

^vMean separation in columns by Duncan's multiple range test, 5% level.

Table 2. Weight loss, color, firmness and decay of nonwrapped and wrapped tomatoes before or after ethylene treatment and stored for 2 wk at 15.6°C^z and after 3 and 7 days at 21°C^z, means of 3 tests, 1984.

| Treatment | Weight loss (%) | Hunter® color | | Firmness (kg) | Decay (%) |
|---------------------------------|---------------------|----------------|----------------|---------------|-----------|
| | | External (a/b) | Internal (a/b) | | |
| 2 wk at 15.6°C | | | | | |
| Nonwrapped—3 days ET | 2.18 a ^y | 1.78 bcd | 1.37 ab | 1.94 c | 0 a |
| Wrapped EHC-50—3 days ET | 0.43 d | 1.74 cd | 1.31 b | 2.49 b | 2 ab |
| Wrapped LDPE—3 days ET | 0.50 d | 1.37 e | 1.07 c | 3.23 a | 2 ab |
| 3 days ET—wrapped EHC-50 | 1.14 c | 1.74 cd | 1.33 b | 2.47 b | 0 a |
| 3 days ET—wrapped LDPE | 1.03 c | 1.70 cd | 1.30 b | 2.52 b | 7 bc |
| 5 days ET—wrapped EHC-50 | 1.75 b | 1.92 ab | 1.41 a | 2.03 c | 9 c |
| 5 days ET—wrapped LDPE | 1.82 b | 1.89 abc | 1.40 a | 1.94 c | 7 bc |
| Nonwrapped—5 days ET | 2.40 a | 1.95 a | 1.41 a | 1.80 c | 7 bc |
| 2 wk at 15.6°C + 3 days at 21°C | | | | | |
| Nonwrapped—3 days ET | 2.46 b | 1.94 abc | 1.42 a | 1.47 d | 4 ab |
| Wrapped EHC-50—3 days ET | 0.51 e | 1.77 d | 1.37 ab | 1.95 bc | 9 ab |
| Wrapped LDPE—3 days ET | 0.63 e | 1.68 d | 1.29 b | 2.40 a | 0 a |
| 3 days ET—wrapped EHC-50 | 1.22 d | 1.79 cd | 1.42 a | 1.94 bc | 13 b |
| 3 days ET—wrapped LDPE | 1.37 d | 1.83 bcd | 1.43 a | 1.95 bc | 4 ab |
| 5 days ET—wrapped EHC-50 | 1.95 c | 1.95 ab | 1.44 a | 1.62 cd | 9 ab |
| 5 days ET—wrapped LDPE | 1.99 c | 2.03 a | 1.43 a | 1.63 cd | 4 ab |
| Nonwrapped—5 days ET | 3.00 a | 2.02 a | 1.45 a | 1.44 d | 11 b |
| 2 wk at 15.6°C + 7 days at 21°C | | | | | |
| Nonwrapped—3 days ET | 3.45 a | 1.89 b | 1.41 a | 1.31 cd | 16 a |
| Wrapped EHC-50—3 days ET | 0.70 d | 1.85 b | 1.36 ab | 1.70 ab | 7 a |
| Wrapped LDPE—3 days ET | 0.80 d | 1.82 b | 1.32 b | 1.87 a | 7 a |
| 3 days ET—wrapped EHC-50 | 1.48 c | 1.84 b | 1.44 a | 1.64 ab | 16 a |
| 3 days ET—wrapped LDPE | 1.96 bc | 1.82 b | 1.42 a | 1.70 ab | 9 a |
| 5 days ET—wrapped EHC-50 | 2.14 b | 2.02 a | 1.44 a | 1.46 bcd | 16 a |
| 5 days ET—wrapped LDPE | 2.51 b | 2.05 a | 1.44 a | 1.51 bc | 16 a |
| Nonwrapped—5 days ET | 3.91 a | 2.04 a | 1.44 a | 1.27 d | 16 a |

^zRelative humidity during 15.6°C storage was 85 to 90% and 88 to 95% during 21°C storage.

^yMean separation in columns by Duncan's multiple range test, 5% level.

Table 3. Concentration of O₂, CO₂ and C₂H₄ within EHC-50 and LDPE film wraps during 3 days C₂H₄ at 21°C, plus 11 days at 15.6°C^z and 7 days at 21°C^z, means of 5 tomatoes, 1984.

| Days in storage | EHC-50 | | | LDPE | | |
|-----------------|---------------------|---------------------|-------------------------------------|--------------------|---------------------|-------------------------------------|
| | O ₂ (%) | CO ₂ (%) | C ₂ H ₄ (ppm) | O ₂ (%) | CO ₂ (%) | C ₂ H ₄ (ppm) |
| 0 | 20.2 a ^y | 0.8 c | 0.4 d | 20.5 a | 0.3 c | 0.1 c |
| 3 | 20.2 a | 1.5 b | 6.4 ab | 19.1 ab | 0.4 c | 1.5 bc |
| 6 | 19.3 a | 2.9 a | 7.7 a | 19.7 ab | 1.4 b | 1.9 bc |
| 9 | 19.6 a | 1.5 b | 5.4 abc | 17.7 b | 2.4 a | 7.9 a |
| 12 | 19.5 a | 1.5 b | 5.7 abc | 17.7 b | 2.4 a | 6.4 ab |
| 15 | 19.9 a | 0.6 c | 8.4 a | 19.3 ab | 1.2 bc | 5.6 ab |
| 18 | 20.0 a | 0.6 c | 5.0 bc | 17.4 b | 1.1 bc | 3.0 bc |
| 21 | 19.6 a | 1.7 b | 1.4 c | 19.6 ab | 0.3 c | 3.3 bc |
| Avg. | 19.8 a ^x | 1.4 a | 5.1 a | 18.9 b | 1.2 a | 3.7 a |

^zRelative humidity during 15.6°C storage was 85 to 90% and 88 to 95% during 21°C storage.

^yMean separation in columns for days in storage by Duncan's multiple range test, 5% level.

^xMean separation in row for each gas by Duncan's multiple range test, 5% level.

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