Proc. Fla. State Hort. Soc. 96: 347-350. 1983.

DECAY, FIRMNESS AND COLOR DEVELOPMENT OF FLORIDA BELL PEPPERS DIPPED IN CHLORINE AND IMAZALIL, AND FILM WRAPPED[1]

W. R. MILLER, D. H. SPALDING AND L. A. RISSE
U.S. Department of Agriculture,
Agricultural Research Service,
2120 Camden Road,
Orlando, FL 32803

Additional index words. bacterial soft rot, alternaria rot, fungicides, *Capsicum annuum.*

Abstract. **Bell peppers (Capsicum annuum L. cv. Grossum) were left untreated or were treated with 200 ppm chlorine (Cl) and 250 ppm imazalil (IM) alone or in combination and then wrapped in heat-shrinkable plastic film and stored together with similarly treated nonwrapped controls for 2 and 3 wk at 45°F plus holding for 7 days at 60°F. Treatments with Cl reduced the incidence of bacterial soft rot (BSR) during storage for 2 wk but not for 3 wk. IM with wrapping was effective in reducing decay after 2 wk at 45°F + 7 days at 60°F and IM, independent of wrapping, reduced decay after 3 wk at 45°F + 3 days at 60°F. No specific treatment consistently reduced decay during 3-wk storage; wrapping in general increased the incidence of decay during 3-wk storage, but had no effect on decay during 2-wk storage. Wrapping reduced color development and maintained firmer pods compared to nonwrapped peppers for 2- and 3-wk storage periods.**

According to the 1982 edition of Agricultural Statistics, the Florida bell pepper industry harvested 7.9 million bu from 19,300 acres valued at $55.6 million (FOB) during the 1981-82 production season. Exports, excluding Canada, for 1979-80, 1980-81 and 1981-82 were 160,000, 20,000 and 8,000 bu, respectively. Serious freeze damage during 1980-81 and 1981-82 resulted in reduced export volume. Postharvest decay of peppers grown in Florida is potentially high principally because of climatic conditions prior to harvest. High humidity and rainfall prior to harvest increase bacterial soft rot, and low temperatures cause chilling injury and increase alternaria rot (5, 7, 8, 9, 12, 15, 16).

Recent studies conducted by Ceponis and Butterfield (3), Risse et al. (12), and McDonald and de Wildt (10) show that bacterial soft rot, caused by *Erwinia carotovora* (L. R. Jones) Holland, and alternaria rot, caused by *Alternaria alternata* (Fr.) Keissler, still cause excessive marketing losses. Several methods have been reported that retard the development of decay in peppers, but most treatments provide only partial control (6, 15). More recently, investigators have explored film wrapping as a technique to prolong shelf life of bell peppers (1). Bussel and Kinigsberger (2) wrapped peppers in several different plastic films and stored them at 45, 54, and 77°F. They reported 1) that wrapping reduced the rate of weight loss compared to nonwrapping, 2) that polyethylene (PE) film retarded color development compared to other films tested, and 3) that O_2 and CO_2 concentrations within wraps depended on both film permeability and storage temperature. They also reported that polyethylene (PE) film resulted in the greatest reduction of weight loss, but due to increased condensation on pods, decay apparently was increased. Hughes et al. (4) stored peppers wrapped in several different films at 68°F and found no differences in pepper condition by film type, but found wrapping to be significantly beneficial in prolonging shelf life compared with nonwrapped peppers; in addition, they found that wrapping did not cause a serious decay problem. Miller and Risse (11) recently found that the individual wrapping of peppers in 3 types of heat-shrinkable plastic film reduced weight loss, but did not reduce the incidence of decay. The principal decay organism in these tests was bacterial soft rot (BSR).

Spalding (14, 15) investigated the effectiveness of imazalil (1-[2-(2,4-dichlorophenyl)-2-(2-propenyloxy) ethyl]-1H-imidazole) to control alternaria decay in peppers and tomatoes and found that IM in solutions greater than 0.01% was 95% effective in inhibiting alternaria rot of peppers. Segall and Dow (13) reported that Cl is effective in preventing bacterial soft rot in tomatoes when it is applied at the site of bacterial contamination but that Cl is ineffective as a protectant when applied before or after contamination.

The purpose of this study is to determine the effect that IM and Cl, alone or combined, has on the control of postharvest decay development of wrapped and nonwrapped bell peppers and the effect of film wrapping on pod firmness and color development.

Materials and Methods

Freshly harvested bell peppers were obtained from a single commercial grower/packer located on the southeastern coast of Florida. All peppers were subjected to similar fertilizer practices during production and were from the first field picking. Pods were selected directly from the grading line after being washed in fresh water of ambient temperature. No fungicide was applied at the packinghouse. Selected pods measuring from 2.75-3.54 inches in diameter were placed in 1 bu waxed fiberboard boxes and returned immediately (4 hr by auto) to the laboratory and prepared for the following treatments:

Nonwrapped	Wrapped
1. Control (no dip)	5. Control (no dip)
2. Chlorine (200 ppm)	6. Chlorine (200 ppm)
3. Imazalil (250 ppm)	7. Imazalil (250 ppm)
4. Cl (200 ppm) + IM (250 ppm)	8. Cl (200 ppm) + IM (250 ppm)

The Cl solution was prepared by adding household bleach containing 5.125% sodium hypochlorite to 10.6 gal of fresh water and adjusting to 200 ppm, with the aid of a color comparator. The IM solution was prepared by adding 0.42 fl oz of 80% w/v stock IM to 10.6 gal of fresh water. Twenty pods at a time were placed into a mesh bag and submerged in the prepared solution for 15 sec. Pods were placed on kraft paper until dry. Clysar EHC-50®, a copolymer heat-shrinkable film, was selected for wrapping pods in treatments 5-8. The film, properties shown in Table 1, was applied to each pepper using a Weldomatic® sealer (model 6001) and a Weldomatic® heat tunnel (model 7001).

In each of 5 different tests, 2 replications of 15 peppers per treatment were prepared and held in separate storage containers. All samples were placed in refrigerated storage at 45°F for 2 and 3 wk. All pods selected for storage were

[1]Mention of a chemical or proprietary product does not constitute a guarantee or warranty by the U.S. Department of Agriculture nor does it imply registration under FIFRA as amended.

Table 1. Properties of Clysar EHC-50®.[z]

Property	Test[y]	Units	Clysar EHC-50®
Thickness (nominal)	—	inches	0.0052
Shrinkage, 250°F	ASTM D 2732	%	50
Stiffness modulus	ASTM D 882	lb./inch	55[x]
Water vapor transmission rate	ASTM E-96 Procedure E	oz/100 inches²/ 24 hr	0.035
O_2 permeability rate	ASTM D 1434	fl oz/100 inches²/ 24 hr atm	13.5
CO_2 permeability rate	ASTM D 1434	fl oz/100 inches²/ 24 hr atm	33.8-50.7
Haze (average)	ASTM D 1003	%	0.8
Gloss at 68°F (min)	ASTM D 2454	(Photocell)	110
Seal strength	Hot wire seal	oz/inch	88.2
Break strength	ASTM D 882	oz/inch	152[w]
Tear strength	ASTM D 1922	oz	0.16

[z]Based on information supplied by the manufacturer.
[y]American Society for Testing and Materials.
[x]Based on modulus 112,000 psi.
[w]Based on tensile 19,000 psi.

visually sound, and they were evaluated after 2 and 3 wk at 45°F, and after additional storage of 3 and 7 days at 60°F.

At each evaluation, each pod was rated for decay, degree of color development and firmness. Decay was scored binomially (yes, no). Peppers showing symptoms of decay were eliminated from the test at each inspection. Color was subjectively rated on a scale of 1-8 based on a visual determination of nongreen surface area: 1 = 0%, green; 2 = <2%; 3 = 2-10%; 4 = 11-25%; 5 = 26-50%; 6 = 51-75%; 7 = >75% and yellow/orange; and 8 = >75% and red in color. Pod firmness was determined subjectively by scoring the degree of tissue yield to applied finger pressure; i.e., 5 = very firm (no yield to pressure), 4 = firm (slight yield to pressure), 3 = moderately firm (moderate yield to pressure), 2 = slightly firm (yields greatly to pressure), and 1 = flaccid (no resistance to pressure).

Results

There was a significant interaction between treatments and storage periods, so that differences among treatments depended on length of storage. Therefore, all results are presented separately for 2-wk storage at 45°F plus 3 and 7 days at 60°F (Table 2) and 3-wk storage at 45°F plus 3 and 7 days at 60°F (Table 3). Each table shows the mean values (responses) for decay, color development and firmness by treatment. The treatment effects were partitioned into their factorial components, both main effects and interactions of main effects, and the significance of these factorial effects are displayed in each respective table. The data for each inspection for the 8 treatments (7 degrees of freedom [df]) were partitioned into df contrasts, to test the main effects of wrap, Cl, IM, and Cl plus IM and their interactions.

Two-wk storage + 7 days at 60°F. There was no average effect of wrapping for decay. For example, after 2-wk storage at 45°F plus 7 days at 60°F, the effect of wrap on decay is shown as nonsignificant and the calculated values for wrap and nonwrap are: wrapped = (33.33 + 23.33 + 17.33 + 16.00)/4 = 22.50, and nonwrapped = (20.67 + 24.00 + 27.33 + 14.67)/4 = 21.67.

There was a significant average effect of Cl for decay at each inspection. Calculating the Cl effect for decay at 7 days at 60°F resulted in the following values: effect of Cl = (24.00 + 14.67 + 23.33 + 16.00)/4 = 19.50, effect of no Cl = (20.67 + 27.33 + 33.33 + 17.33)/4 = 24.66. The effect of Cl was independent of wrapping for decay. No Cl vs. Cl in wrap = (33.33 + 17.33 – 23.33 – 16.00)/2 = 5.66, and no Cl vs. Cl in nonwrap = (20.67 + 27.33 – 24.00 – 14.67)/2 = 4.66. There was an effect of IM on decay following the inspection after 7 days at 60°F; effect of IM = (27.33 + 14.67 + 17.33 + 16.00)/4 = 18.83 and effect of no IM = (20.67 + 24.00 + 33.33 + 23.33)/4 = 25.33, and the effect of IM depended on wrapping, no IM vs. IM in wrap = (33.33 + 23.33 – 17.33 – 16.00)/2 = 11.66 and no IM vs. IM in nonwrap = (20.67 + 24.00 – 27.33 – 14.67)/2 = 1.34. The effect of IM at this inspection did not depend on the presence of Cl; no IM vs. IM in presence of Cl = (24.00 + 23.33 – 14.66

Table 2. Decay, color development and firmness of peppers held 2 wk at 45°F plus 3 and 7 days at 60°F by treatment.

Treatments	Decay[z] 2 wk at 45°F (%)	Decay Plus 3 days at 60°F (%)	Decay Plus 7 days at 60°F (%)	Color[y] 2 wk at 45°F (mean)	Color Plus 3 days at 60°F (mean)	Color Plus 7 days at 60°F (mean)	Firmness[x] 2 wk at 45°F (mean)	Firmness Plus 3 days at 60°F (mean)	Firmness Plus 7 days at 60°F (mean)
TR 1 No wrap control	7.33	11.33	20.67	1.37	1.94	2.80	4.56	4.31	4.10
TR 2 No wrap Cl[w]	4.67	12.00	24.00	1.25	1.85	2.46	4.58	4.32	4.07
TR 3 No wrap IM[w]	12.00	17.33	27.33	1.40	2.03	2.72	4.61	4.32	4.07
TR 4 No wrap Cl + IM	5.33	9.33	14.67	1.45	1.99	2.72	4.71	4.35	4.06
TR 5 Wrap control	4.67	17.33	33.33	1.29	1.58	2.05	4.91	4.84	4.74
TR 6 Wrap Cl	7.33	14.00	23.33	1.35	1.68	2.03	4.97	4.84	4.67
TR 7 Wrap IM	9.33	12.67	17.33	1.36	1.62	1.93	4.94	4.82	4.76
TR 8 Wrap Cl + IM	4.00	8.67	16.00	1.19	1.48	1.92	4.93	4.80	4.70
Factorial effects[v]									
Wrap	0.50	0.69	0.72	0.14	<0.01	<0.01	<0.01	<0.01	<0.01
Cl	0.05	0.03	0.03	0.41	0.34	0.42	0.17	0.97	0.48
Wrap X Cl	0.26	1.00	0.83	0.86	0.93	0.50	0.57	0.76	0.71
IM	0.26	0.32	0.01	0.49	0.55	0.91	0.14	0.99	0.99
Wrap X IM	0.50	0.50	0.03	0.13	0.38	0.37	0.12	0.62	0.66
Cl X IM	0.05	0.16	0.44	0.82	0.55	0.44	0.95	0.99	0.99
Wrap X Cl X IM	0.50	0.23	0.01	0.06	0.37	0.50	0.27	0.84	0.96

[z]% of pods decayed per treatment.
[y]Mean color score ξ (no. fruit X score) ÷ total no. fruit in sample.
[x]Mean firmness score ξ (no. fruit X score) ÷ total no. fruit in sample.
[w]Cl = chlorine; IM = imazalil.
[v]Values ≤ 0.05 are significant at the 5% level by factorial effect analysis.

Table 3. Decay, color development and firmness of peppers held 3 wk at 45°F plus 3 and 7 days at 60°F by treatment.

	Decay[z]			Color[y]			Firmness[x]		
Treatments	3 wk at 45°F (%)	Plus 3 days at 60°F (%)	Plus 7 days at 60°F (%)	3 wk at 45°F (mean)	Plus 3 days at 60°F (mean)	Plus 7 days at 60°F (mean)	3 wk at 45°F (mean)	Plus 3 days at 60°F (mean)	Plus 7 days at 60°F (mean)
TR 1 No wrap control	6.67	14.47	31.13	1.67	2.24	2.95	4.47	4.32	4.15
TR 2 No wrap Cl[w]	8.87	19.47	28.33	1.59	2.20	2.81	4.52	4.32	4.02
TR 3 No wrap IM[w]	11.67	15.53	26.13	1.55	2.02	2.83	4.44	4.31	4.14
TR 4 No wrap Cl + IM	6.13	8.87	16.67	1.59	1.94	2.78	4.40	4.39	4.19
TR 5 Wrap control	17.53	24.20	34.20	1.34	1.80	2.00	4.94	4.78	4.64
TR 6 Wrap Cl	13.33	25.00	39.20	1.23	1.48	1.65	4.96	4.73	4.77
TR 7 Wrap IM	15.87	21.67	42.53	1.39	1.45	1.69	4.90	4.74	4.69
TR 8 Wrap Cl + IM	10.87	17.53	35.87	1.33	1.48	1.72	4.88	4.76	4.69
Factorial effects[v]									
Wrap	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Cl	0.74	0,63	0.17	0.31	0.19	0.32	0.98	0.84	0.90
Wrap X Cl	0.36	0.87	0.37	0.49	0.51	0.81	0.97	0.74	0.59
IM	0.91	0.05	0.17	0.94	0.02	0.44	0.46	0.86	0.59
Wrap X IM	0.32	0.95	0.07	0.15	0.56	0.87	0.92	0.83	0.75
Cl X IM	0.11	0.07	0.14	0.35	0.46	0.39	0.73	0.61	0.66
Wrap X Cl X IM	0.28	0.50	0.67	0.79	0.23	0.55	0.90	0.97	0.48

[z]% of pods decayed per treatment.
[y]Mean color score ξ (no. fruit X score) ÷ total no. fruit in sample.
[x]Mean firmness score ξ (no. fruit X score) ÷ total no. fruit sample.
[w]Cl = chlorine; IM = imazalil.
[v]Values ≤ 0.05 are significant at the 5% level by factorial effect analysis.

– 16.00)/2 = 8.33, and no IM vs. IM in absence of Cl = (20.67 + 33.33 – 27.33 – 17.33)/2 = 4.67.

There was a significant average effect of wrapping to retard color development after the storage period of 2 wk at 45°F, and wrapping had a significant effect on retarding softening at each inspection.

Three-wk storage plus 7 days at 60°F. There was a significant average effect of wrap for decay, color and firmness at each inspection. For example, the calculated wrapping effect for decay at the inspection after 7 days at 60°F is: effect of wrap = (34.20 + 39.20 + 42.53 + 35.87)/4 = 37.95 and effect of nonwrapped = (31.13 + 28.33 + 26.13 + 16.67)/4 = 25.57. Wrapping significantly increased the incidence of decay. Imazalil had an effect on reducing decay at 3 days at 60°F; effect of IM = (15.53 + 8.87 + 21.67 + 17.53)/4 = 15.9, and effect of no IM = (14.47 + 19.47 + 24.20 + 25.00)/4 = 20.79 and IM was not dependent on wrapping. No other treatment or combination of treatments significantly reduced decay. Wrapping did effectively decrease color development and significantly reduced softening of the pods during storage.

Observed differences between 2- and 3-wk storage results. There are several important differences in results between the 2- and 3-wk storage periods: 1) during 2 wk at 45°F + 7 days at 60°F storage wrapping had no effect on decay, whereas during the 3-wk storage, wrapping significantly increased the incidence of decay; 2) during the 2-wk storage, Cl consistently had an effect on reducing decay, whereas during the 3-wk storage there was no Cl effect on decay; and 3) IM had a significant effect on reducing decay and IM was dependent on wrapping after 2 wk at 45°F plus 7 days at 60°; and IM had a significant effect on decay after 3 wk at 45°F + 3 days at 60°, but IM was independent of wrapping.

These findings show that film wrapping slows color development and pod softening of peppers. Our findings differ from most other studies in that decay (BSR) developed during storage regardless of treatment, whereas others have reported that decay was generally no real problem. This study revealed that film wrapping may not increase the incidence of decay when peppers are held for 2 wk at 45°F compared with nonwrapped peppers, but that wrapping will generally increase the incidence of decay regardless of treatment when they are stored for 3 wk. Only with IM in conjunction with wrapping at a single inspection (2 wk at 45°F + 7 days at 60°F) was there a benefit in reduced decay due to wrapping. Therefore, in general, film wrapping of peppers is not an effective method for consistent decay control when used in conjunction with Cl or IM, and wrapping alone will have no effect on decay or will increase decay, depending on length of storage. Additional observations made during this study suggest that film wrapping will reduce or prevent decay caused by secondary infection, because the film prevents decayed pods from coming into direct contact with sound pods. Wrapped pods with decay are also easily removed from shipping containers without leakage.

Postharvest decay control of Florida peppers remains an important problem that demands continued investigation. Until an effective decay control method is developed to reduce the incidence of BSR in peppers, shippers will not be able to ship them successfully to distant markets requiring 2 and 3 wk for delivery.

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Proc. Fla. State Hort. Soc. 96: 350-352. 1983.

FILM WRAPPING AND DECAY OF EGGPLANT[1]

L. A. Risse and W. R. Miller
U.S. Department of Agriculture,
Agricultural Research Service,
2120 Camden Road,
Orlando, FL 32803

Additional index words. heat-shrinkable films, weight loss, firmness, color, chlorine, export.

Abstract. **In 3 storage tests, Florida eggplant** (Solanum melongena **L.) wrapped in paper tissue or in 1 of 3 different plastic films were stored at 45°F for 1, 2 and 3 wk followed by 60°F for 3 and 7 days to simulate domestic and export shipment and retail handling. After storage, the eggplants were weighed and evaluated for weight loss, firmness, color of stem end, and decay. Generally, wrapping eggplants in sealed plastic films reduced weight loss, maintained firmness, but increased decay significantly compared with tissue-wrapped eggplants or eggplants wrapped in perforated film. Because decay was increased by sealing the eggplants in film, an additional test was conducted which indicated that the use of chlorine (Cl) would reduce the incidence of decay, although eggplants treated with Cl and film-wrapped still had significantly more decay than those treated with Cl and tissue-wrapped.**

During the 1981-82 season, Florida produced ca. 1.7 million bu of eggplants (*Solanum melongena* L.) valued at ca. $9.6 million (1). Some eggplants have been exported, mainly to Europe. For the last 4 yr exports have ranged from 3,000 to 27,000 1-bu boxes (1). Eggplants are not adapted to long-term storage; they cannot be expected to keep satisfactorily even at optimum temperatures of 45° to 50°F for more than about a week and still retain good condition during retailing (3). Eggplants are subject to chilling injury below 45°F, and to shriveling and decay above 45°F (4). Many European importers have stated that they would import more eggplants from the U.S. if arrival condition could be improved (less shriveling and decay).

In the past few years, many researchers have studied film wrapping of fruits and vegetables (2). 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 decay by preventing secondary infection of fruit packed in the same box. Eggplants benefit from packaging in ventilated bags or over-wrapped trays through reduced water loss and physical injury (6). It has also been suggested that eggplants can be wrapped in shrink film that is perforated, or incompletely sealed at one end (5).

The purpose of this study was to determine the physiological effects on quality factors of eggplants when individually wrapped in 3 selected types of films and stored at 45°F for 1-3 wk.

[1]Mention of a trademark, warranty, proprietary product, or vendor does not constitute a guarantee by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

Materials and Methods

Three tests were conducted at ca. 5-wk intervals from December to April during the 1982-83 season. The eggplants were grown and packed by one grower in the Boynton Beach, Florida, area. The eggplants were not precooled or treated with bactericides or fungicides. After eggplants were field-packed in 1-bu fiberboard boxes, they were brought back to the laboratory at Orlando, Florida.

In Orlando, about 4 hr after harvest, the eggplants were randomly sorted (with only obviously bruised or decayed fruit removed) into lots of 12 eggplants per treatment. The treatments were: 1) control—tissue wrapped (commonly practiced by many Florida growers); 2) EHC-50—wrapped in a biaxially oriented, heat-shrinkable copolymer film of 0.5 mil nominal thickness; 3) stretch—wrapped in stretchable, polyvinyl chloride film of 0.65 mil nominal thickness; and 4) perforated—wrapped in a perforated, biaxially oriented, heat-shrinkable copolymer film of 0.75 mil nominal thickness. The perforated film contained 25 perforations (each 1/16 inch diameter) per inch^2. For the decay-control study, 4 additional treatments were randomly selected: 1) control—tissue wrapped, 2) control—treated with 200 ppm of chlorine (Cl) and tissue wrapped; 3) wrapped—EHC-50 film; and 4) wrapped—treated with 200 ppm Cl and wrapped in EHC-50 film. For all 4 treatments, the eggplants were dipped in water either with or without Cl and allowed to dry before wrapping. The tissue- and stretch-wrapped eggplants were wrapped by hand. Those wrapped in EHC-50 and perforated film 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 with temperatures from 325-350°F, but maximum surface temperature of the eggplants was ca. 100°F for a few seconds. Weight of each eggplant was measured using a Sartorius® balance (Model 1204 MP).

After treatment and wrapping, each lot of 12 eggplants was packed in a 1/2-bu, full-telescope, fiberboard box for storage. All treatments were placed in the same refrigerated storage room at 45°F and 85-90% relative humidity for either 1, 2, or 3 wk. Following initial storage, the eggplants were weighed, evaluated, and placed at 60°F and 90-95%