Biphenyl Residues, Decay, and Soilage in Oranges: Effect of Carton Ventings, Barriers, and Biphenyl Dosages During Storage

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Biphenyl Residues, Decay, and Soilage in Oranges: Effect of Carton Ventings, Barriers, and Biphenyl Dosages During Storage

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Summary

Biphenyl residues in navel oranges held with biphenyl-treated pads were higher when oranges were stored in nonvented cartons than in cartons with ½- and 1-inch vents. The rate of biphenyl depletion from the pads was similar in all three types of cartons.

Barriers of aluminum foil, placed on both sides of a biphenyl-treated pad reduced the rate of depletion from the pads 75 percent, and barriers of wax paper 20 percent. Polykraft papers were ineffective as barriers. Barriers of aluminum foil decreased biphenyl residues in navel oranges more than wax paper or polykraft paper. Amounts of decay and soilage of oranges were similar with all three types of barriers.

Navel oranges held with two standard (2.38 grams biphenyl) pads per carton absorbed more biphenyl than oranges held with one pad. After 4 weeks' storage at 50° F. plus 2 weeks at 70°, biphenyl pads were nearly depleted. Oranges in cartons with one or two standard pads had similar amounts of decay and soilage. Oranges in cartons with one pad containing 1.38 grams biphenyl had more soilage and decay than those held with standard pads.

Biphenyl pads in cartons of Valencia oranges lost 26 percent of the biphenyl after 3 days at 70° F., 92 percent after 3 days at 70° plus 3 weeks at 42° plus 2 weeks at 70°, and 86 percent after 2 weeks at 70°. Only small differences in biphenyl absorption by Valencia oranges resulted from addition and removal of biphenyl pads after various intervals during storage.

Oranges in vented cartons without biphenyl pads stored in the same room with vented cartons of biphenyl-treated oranges absorbed biphenyl from the atmosphere of the storage room. Oranges held without biphenyl pads 3 days at 70° F. plus 3 weeks at 42° plus 2 weeks at 70° absorbed 78 percent and those held 2 weeks at 70° absorbed 51 percent of the quantity of biphenyl absorbed by similarly stored biphenyl-treated fruit.

When biphenyl pads were present or absent at various intervals during storage, more soiled than decayed fruit resulted; oranges in cartons with biphenyl pads present during the entire storage had equal amounts of soiled and decayed fruit. Soilage and decay decreased as exposure to biphenyl increased. Results indicate that for best control of decay and soilage, biphenyl should be present during the early stages of infection, as well as the remainder of the storage period.

Wrapping Valencia oranges individually in polyethylene film and holding without biphenyl pads controlled decay as well as standard exposure to biphenyl, and soilage was eliminated. Polykraft paper between layers of fruit without biphenyl pads did not control decay or soilage.

Biphenyl absorption by Valencia oranges was not affected by different amounts of decayed fruit in the cartons.

Valencia oranges held with biphenyl 2 weeks at 70° F. in nonvented cartons exceeded both the U.S. (110 p.p.m.) and European Economic Community (EEC) (70 p.p.m.) biphenyl tolerances, and those held in vented cartons exceeded the EEC tolerance.

[1] Stationed in Pomona, Calif.

Introduction

Biphenyl has been used to control decay and soilage in citrus fruit since Tomkins first reported its effectiveness in 1935 (*9, pp. 129–131*).[2] The commercial practice is to use kraft paper treated with biphenyl at the rate of 4 to 5 pounds per thousand square feet. This usage insures that an adequate quantity of biphenyl will be available during the marketing period for both domestic and overseas shipments. Two pads of this treated paper are placed in each carton of citrus fruit during packaging, placement varying with individual shippers.

The legal tolerance for biphenyl residues in the United States in citrus fruits has been 110 p.p.m. since 1956 (*4, 5*). The European Economic Community (EEC) adopted a legal tolerance of 70 p.p.m. in 1968 (*2*). Previous studies[3] have indicated that oranges might exceed the EEC's tolerance because of the prolonged storage and sometimes inadequate refrigeration during shipping.

Biphenyl residues in oranges are not lowered substantially by decreasing the dosage per carton, although they are reduced somewhat by proper placement of the biphenyl pads in the carton (*7*). Biphenyl residues might be reduced by controlling the exposure of the fruit to biphenyl or by obstructing the passage of biphenyl to the fruit.

The purpose of this study was to determine to what extent levels of biphenyl residue, decay, and soilage in oranges could be controlled (1) by the addition and removal of biphenyl after different intervals during storage, or (2) by the placement of barriers between the fruit and the biphenyl-treated pads. Another objective was to determine whether decay and soilage could be controlled without the use of biphenyl (1) by wrapping oranges individually in polyethylene film and storing, and (2) by storing unwrapped fruit with polyethylene-coated kraft paper placed between the layers of fruit. Length and temperatures of storage simulated those required for shipment to western European ports and distribution to the various EEC markets.

Experimental Methods

Fruit and Packaging Materials

Oranges.—Washington navel and Valencia oranges were washed and waxed by standard packinghouse procedures. The oranges, size 138 packed in five layers per carton, were brought to storage temperature and repacked in specified cartons with biphenyl pads in appropriate positions, if used. Oranges, inoculated with spores of *Penicillium* blue and green molds, were placed at random in each layer during repacking. Three cartons of oranges were used for each variable.

Cartons.—Three types of cartons were used in this study. They were (1) standard cartons vented with eighteen 1-inch holes, six on the top, six on the bottom, and three on each of two sides; (2) cartons vented with eighteen ½-inch holes matching those in standard cartons; and (3) cartons without holes (nonvented).

Biphenyl pads.—The pads, from unbleached kraft paper, 48-pound basic weight, contained the following levels of biphenyl:

(1) 5.13 pounds per 1,000 square feet (standard pads, biphenyl analyses of 59 pads ranged between 2.21 and 2.53 with a mean of 2.38 grams biphenyl per pad and a standard deviation of 0.07); and

(2) 2.93 pounds per 1,000 square feet (biphenyl analyses of 54 pads ranged between 1.29 and 1.45 with a mean of 1.38 grams biphenyl per pad and a standard deviation of 0.05).

Barriers.—Barriers used in the study were (1) kraft paper (polykraft), 50-pound basic weight, with an 8-pound polyethylene coating (Crown Zellerbach Corp.), (2) standard household aluminum foil, and (3) household wax paper. These materials were cut the same size with six 1-inch holes to match standard biphenyl pads. One barrier on each side of the biphenyl pad in the carton prevented the pad from coming in direct contact with the fruit and obstructed the passage of biphenyl from the pad.

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[2] Italic numbers in parentheses refer to Literature Cited, p. 16.

[3] RYGG, G. L. TESTS OF OVERSEAS SHIPMENTS OF CALIFORNIA CITRUS FRUIT—INTERRELATIONS BETWEEN FRUIT CONDITIONS, BIPHENYL CONTENT, TRANSIT TEMPERATURE, DELAYED LOADING, AND BIPHENYL PAD PLACEMENT. U.S. Dept. Agr. Market. Res. Rpt. 830. (In preparation.)

Plastic wraps.—Cryovac-type L, an oriented-polyethylene film, was used to wrap fruit individually.

Storage Tests

Series A Tests: Different Types of Carton Ventings, Barriers, and Biphenyl Dosages

Navel oranges were used in this series of tests. Each carton of oranges contained 10 fruits inoculated with spores of *Penicillium* blue and green molds. The effects of carton venting, biphenyl dosages, and barriers on biphenyl residues, decay, and soilage, were determined. Lengths and temperatures (°F.) of storage were (1) 3 weeks at 50° plus 1 and 2 weeks at 70° and (2) 4 weeks at 50° plus 1 and 2 weeks at 70°. Pad placements, types of carton venting, biphenyl dosages, and barriers were as follows:

(1) One pad (2.38 grams biphenyl) placed between the third and fourth layers of oranges in nonvented cartons and cartons with ½- and 1-inch vents;

(2) One pad (2.38 grams biphenyl) without barriers, with polykraft barriers, with aluminum foil barriers, and with wax paper barriers, were placed between the third and fourth layers of oranges in cartons with 1-inch vents;

(3) One pad (1.38 or 2.38 grams biphenyl) placed between the third and fourth layers of oranges in cartons with 1-inch vents;

(4) Two pads (2.38 grams biphenyl each), one placed between the first and second and one between the fourth and fifth layers of oranges in cartons with 1-inch vents.

Series B Tests: Addition and Removal of Biphenyl Pads After Different Intervals During Storage

Valencia oranges were packed in cartons with 1-inch vents in this series of tests. Each carton contained five oranges inoculated with spores of *Penicillium* green mold; one inoculated fruit was placed at random in each layer of fruit. Two pads, containing 2.38 grams biphenyl each, were placed in each carton, one at the bottom and one at the top. To minimize disturbing the fruit when pads were added and removed, the bottoms of the cartons were taped shut rather than glued in the normal manner. Biphenyl residues, decay, and soilage associated with the addition and the removal of the pads after different intervals during storage were compared. Lengths and temperatures (°F.) of storage were (1) 3 days at 70°, (2) 3 days at 70° plus 3 weeks at 42°, (3) 3 days at 70° plus 3 weeks at 42° plus 1 week at 70°, and (4) 3 days at 70° plus 3 weeks at 42° plus 2 weeks at 70°. Treatments were as follows:

(1) No biphenyl pads used during any part of the storage;

(2) Biphenyl pads present during the first 3 days' storage at 70° only, then removed for the remaining 3 weeks at 42° plus 1 and 2 weeks at 70°;

(3) Biphenyl pads present during the first 3 days' storage at 70° plus 3 weeks at 42°, then removed for the final 1 and 2 weeks' storage at 70°;

(4) Biphenyl pads present during the entire storage;

(5) No biphenyl pads used during the first 3 days' storage at 70°, then pads added for the remaining 3 weeks at 42° plus 1 and 2 weeks at 70°;

(6) No biphenyl pads used during the first 3 days at 70° plus 3 weeks at 42°, then added for the final 1 and 2 weeks at 70°.

These treatments are shown in figure 1.

Series C Tests: Storage Without Biphenyl With Polykraft Paper Between Layers of Fruit or With Oranges Individually Wrapped in Polyethylene

Valencia oranges were packed in cartons with 1-inch vents in these tests. The number of inoculated fruits and the lengths and temperatures of storage were the same as that for series B. The number of oranges decayed and soiled were tallied for the following treatments:

1. Oranges packed in the normal manner with and without biphenyl pads;

2. Oranges individually wrapped with polyethylene film and held without biphenyl pads;

3. Oranges packed with one sheet of polykraft paper placed under each layer of oranges (polyethylene-coated side faced up) and held without biphenyl pads.

Series D Tests: Effect of Different Levels of Inoculated Fruit and of Carton Venting on Biphenyl Absorption During Storage for 2 Weeks at 70° F.

Valencia oranges were held for 1 and 2 weeks

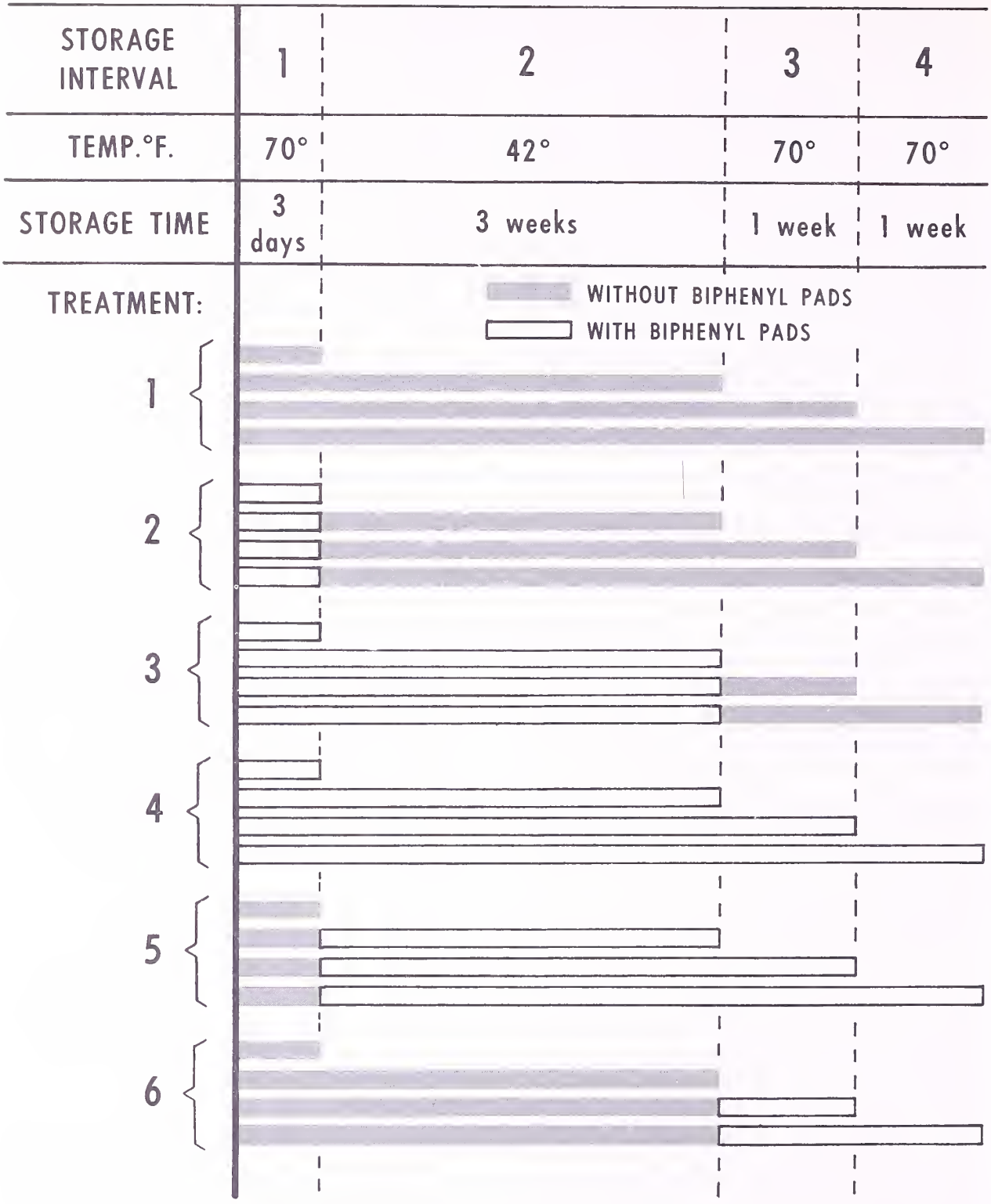

FIGURE 1.—Addition and removal of biphenyl pads after different intervals during storage.

with two biphenyl pads per carton in this series. One pad was placed between the first and second and one between the fourth and fifth layers of fruit in nonvented cartons and in cartons with 1-inch vents. Each pad contained 2.38 grams biphenyl. Oranges inoculated with spores of *Penicillium* green mold represented 0, 5, 10, and 15 percent of the fruit in the cartons. Biphenyl residues, decay, and soilage associated with the amount of decayed fruit in the cartons were compared.

Fruit and Pad Sampling

After the required storage, the number of decayed oranges and sound oranges soiled by *Penicillium* spores were counted. Twenty sound oranges were selected by random numbers (*1, pp. 299–300*) for biphenyl analysis. One-fourth-inch disks were punched out from each pad both before and after use and analyzed for biphenyl content.

Biphenyl Analyses

Biphenyl residues were determined by thin layer chromatography and spectrophotometric measurements according to Norman and coworkers (*6*). Duplicate samples of 300 grams of fruit from each carton and 0.1 to 1.0 grams of paper from biphenyl pads were analyzed. Biphenyl content for fruit represents parts per million (p.p.m.) of biphenyl on the basis of fresh fruit weight and grams per carton on the basis of 18 kilograms of fruit per carton. Biphenyl content of pads represents grams per pad and grams per carton. All results reported are averages of three cartons of fruit.

Results and Discussion

Biphenyl Residues

Series A Tests

Different carton venting during storage for 3 and 4 weeks at 50° F. plus 1 and 2 weeks at 70°.—Figure 2 shows depletion of biphenyl from pads in cartons with different ventings during 4 weeks' storage at 50° F. plus 2 weeks at 70°. In cartons having one pad (2.38 grams biphenyl), 50 percent of the biphenyl was lost from the pads in nonvented cartons after 4 weeks at 50° whereas 59 percent was lost from the pads in cartons with ½- and 1-inch vents. During 4 weeks' storage at 50° plus 2 weeks at 70°, 94 percent of the biphenyl was depleted from the pads regardless of type of venting. Similar pads in cartons with ½- and 1-inch vents lost 48 percent biphenyl during 3 weeks' storage at 50° and 94 percent after 3 weeks at 50° plus 2 weeks at 70°.

Navel oranges held with one pad (2.38 grams biphenyl) (fig. 2) absorbed slightly more biphenyl in nonvented cartons than oranges in cartons with ½- and 1-inch vents during 4 weeks' storage at 50° F. During 4 weeks' storage at 50° plus 2 weeks at 70°, oranges in nonvented cartons absorbed 25 percent more biphenyl than oranges held in either type of vented cartons. The biphenyl content of the oranges exceeded the 70 p.p.m. EEC tolerance by 12 p.p.m. at the end of storage. Oranges held in nonvented cartons with one pad absorbed as much biphenyl as oranges held in cartons with 1-inch vents and two pads (standard packaging) during the same storage periods and temperatures. Oranges absorbed 68 percent of the biphenyl that volatilized from the pads in nonvented cartons, 52 percent in cartons with ½-inch vents, and 47 percent in cartons with 1-inch vents during 4 weeks' storage at 50° plus 2 weeks at 70°.

Different barriers during storage for 4 weeks at 50° F. plus 1 and 2 weeks at 70°.—Figure 3 depicts the depletion of biphenyl pads with different barriers placed on each side of the pad. During 4 weeks' storage at 50° F. plus 2 weeks at 70°, the pads without barriers lost 95 percent biphenyl, those with polykraft barriers 91 percent, those with aluminum foil barriers 20 percent, and those with wax barriers 75 percent.

Navel oranges (fig. 3) with aluminum foil barriers absorbed 18 percent less biphenyl and those with wax paper barriers absorbed 5 percent less than those in cartons without barriers. Polykraft barriers did not decrease absorption. Oranges absorbed 47 percent of the biphenyl that volatilized from pads without barriers, 53 percent with polykraft barriers, 54 percent with wax paper barriers, and more than 100 percent with aluminum foil

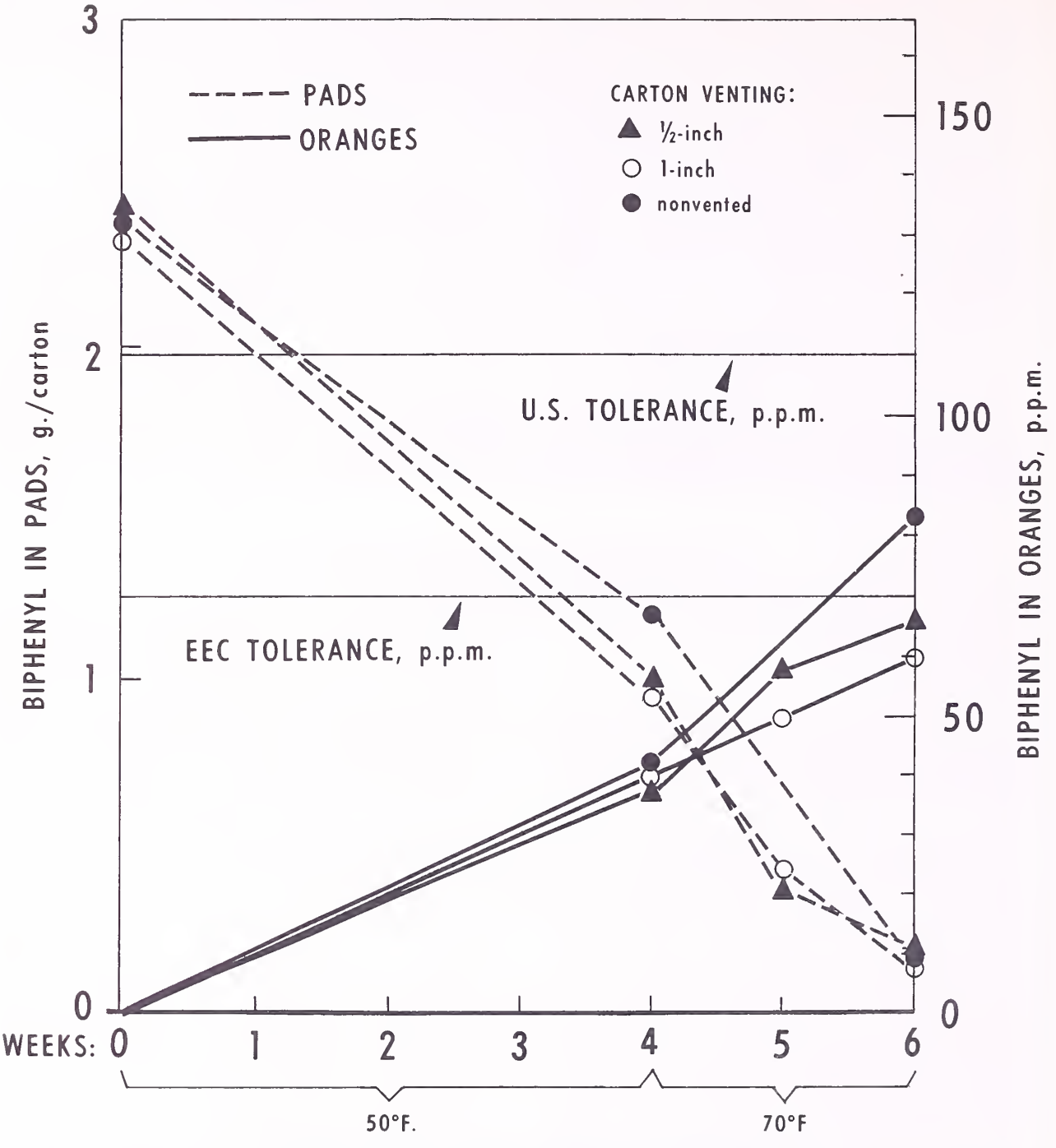

FIGURE 2.—Depletion of biphenyl pads (2.38 grams biphenyl per pad) and biphenyl absorption by navel oranges when held in cartons with different types of venting.

barriers during 4 weeks' storage at 50° plus 2 weeks at 70°. Absorption of more biphenyl by the fruit than left the pads resulted from absorption of biphenyl from the atmosphere of the storage room.

Different biphenyl dosages during storage for 3 and 4 weeks at 50° F. plus 1 and 2 weeks at 70°.—The effect of different biphenyl dosages in standard vented cartons on the depletion of biphenyl pads is shown in figure 4. One pad (2.38 grams bi-

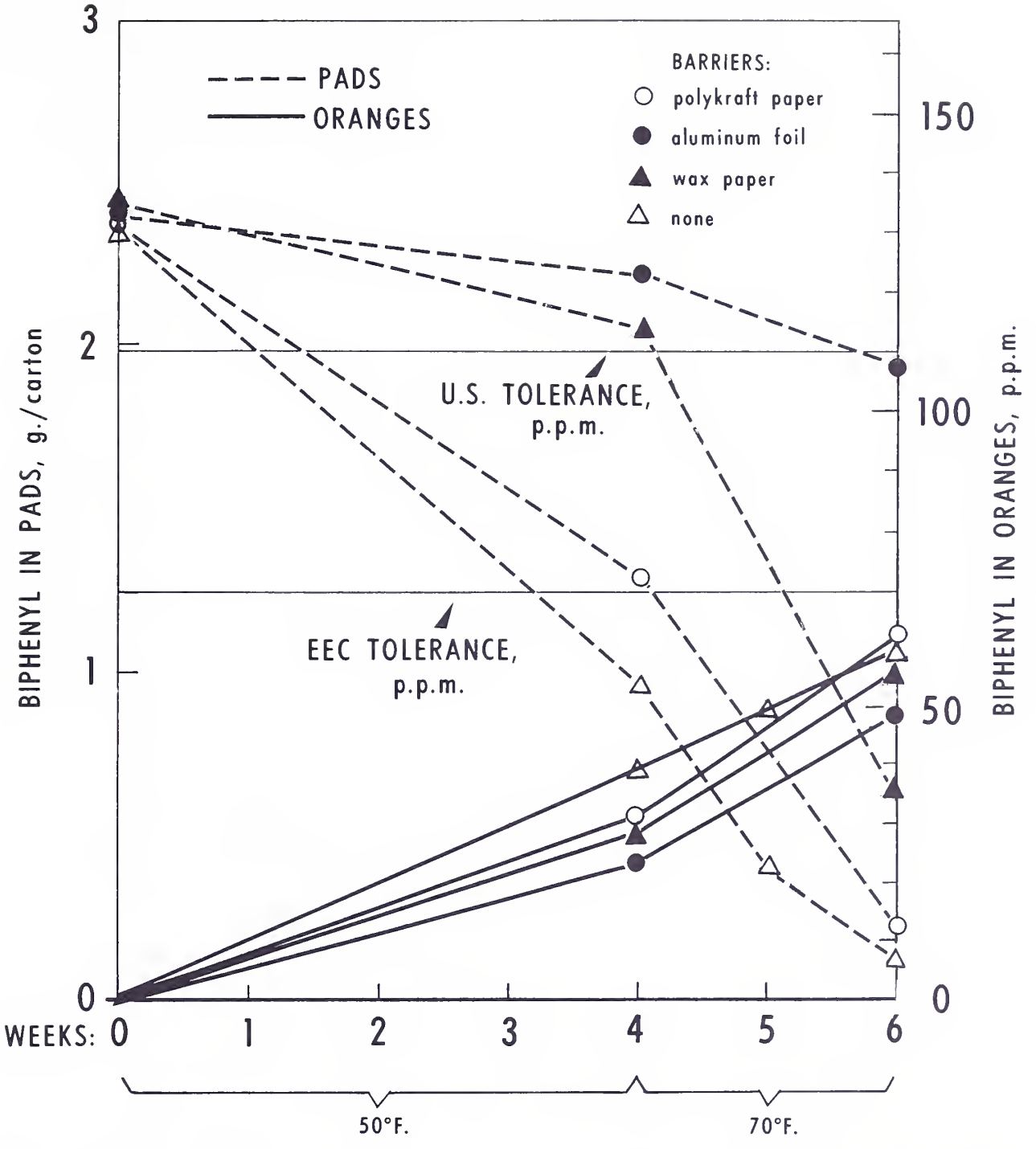

FIGURE 3.—Depletion of biphenyl pads and biphenyl absorption by navel oranges stored with various barriers on both sides of one pad (2.38 grams biphenyl) per carton.

phenyl) per carton lost 95 percent biphenyl; one pad (1.38 grams biphenyl) per carton, 98 percent; and two pads (2.38 grams biphenyl each), 91 percent biphenyl during 4 weeks' storage at 50° plus 2 weeks at 70°.

Navel oranges stored for 4 weeks at 50° F. plus

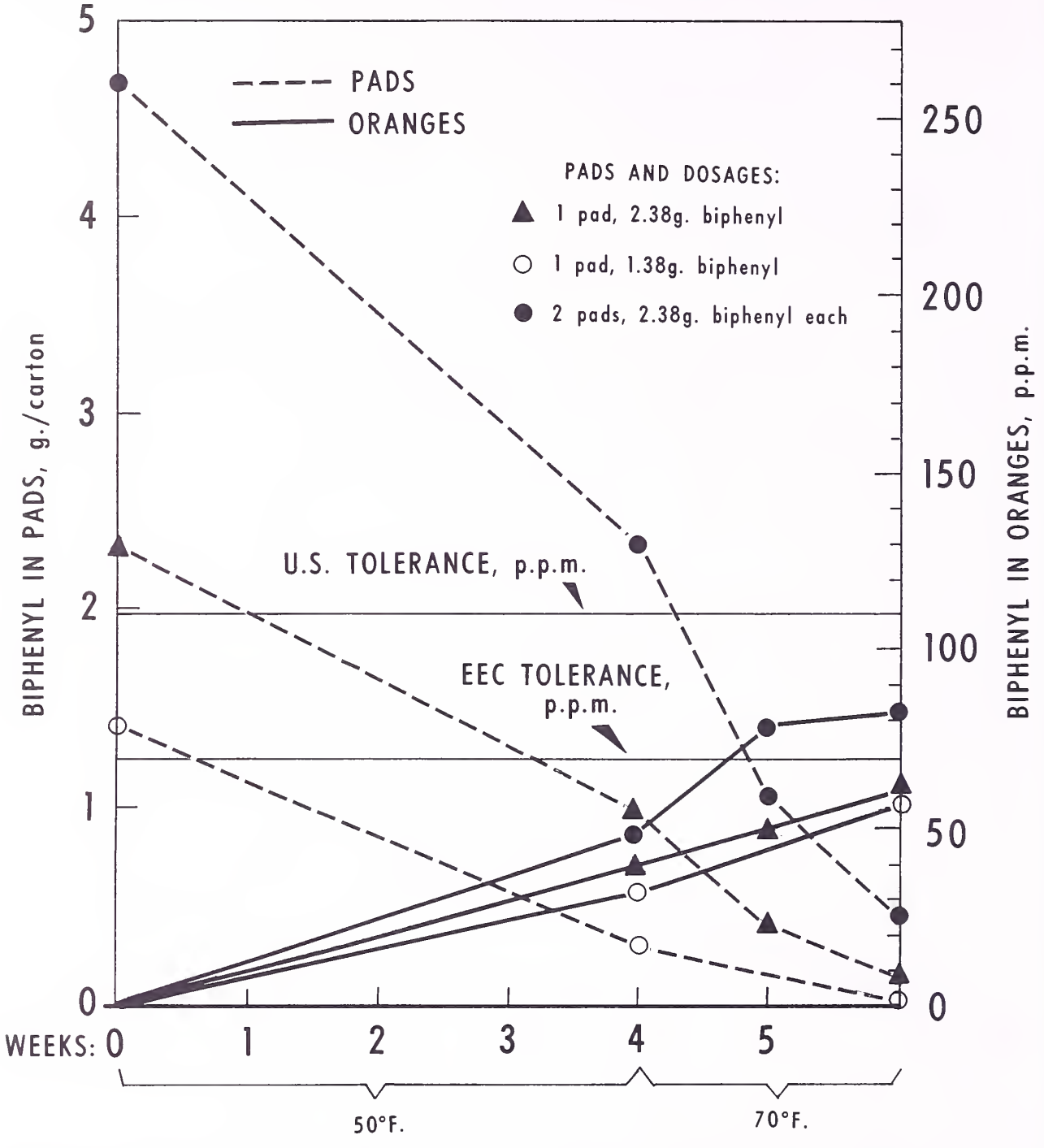

FIGURE 4.—Depletion of biphenyl pads and biphenyl absorption by naval oranges stored with different biphenyl dosages in cartons with 1-inch vents.

2 weeks at 70° with two pads per carton with 1-inch vents absorbed 30 percent more biphenyl than those held with one pad per carton with either 1.38 or 2.38 grams biphenyl per pad (fig. 4). Biphenyl residues in oranges with two pads per carton exceeded the 70 p.p.m. EEC tolerance by

12 p.p.m. at the end of storage. During 3 weeks' storage at 50° plus 2 weeks at 70°, navel oranges absorbed 54 p.p.m. with one pad and 69 p.p.m. with two standard pads per carton. Biphenyl residues increased in oranges as the number of pads increased in the carton, regardless of biphenyl dosage (*7*). Navel oranges absorbed 46 percent of the biphenyl that volatilized from one pad with 2.38 grams biphenyl, 75 percent from one pad with 1.38 grams biphenyl, and 35 percent from two pads with 2.38 grams biphenyl each.

Series B Tests

Removal of biphenyl pads after different intervals during storage for 3 days at 70° F. plus 3 weeks at 42° plus 1 and 2 weeks at 70°.—Figure 5 shows the depletion of pads with removal of biphenyl pads after different intervals during storage (each carton contained two pads with 2.38 grams biphenyl each). The pads lost 28 percent biphenyl during 3 days at 70°, 50 percent during 3 days at 70° plus 3 weeks at 42°, and 92 percent during 3 days at 70° plus 3 weeks at 42° plus 2 weeks at 70°.

Only small differences were found between biphenyl residues in Valencia oranges held the entire storage period with biphenyl pads and those in which the pads were removed at various intervals during storage (fig. 5). Oranges continued to absorb biphenyl from the atmosphere of the storage room after the pads were removed. The biphenyl-treated Valencias absorbed 53 percent of the biphenyl that volatilized from the pads during 3 days at 70°, 31 percent of that volatilized from the pads during 3 days at 70° plus 3 weeks at 42°, and 27 percent of that volatilized from the pads during 3 days at 70° plus 3 weeks at 42° plus 2 weeks at 70°.

Addition of biphenyl pads after different intervals during storage for 3 days at 70° F. plus 3 weeks at 42° plus 1 and 2 weeks at 70°.—Depletion of biphenyl pads with pads added at different intervals during storage are shown in figure 6. Each standard carton contained two biphenyl pads with 2.38 grams biphenyl per pad. The pads lost 92 percent biphenyl during 3 days storage at 70° plus 3 weeks at 42° plus 2 weeks at 70°, 92 percent during 3 weeks at 42° plus 2 weeks at 70°, and 86 percent during 2 weeks at 70°.

Only small differences in the amount of biphenyl absorbed by oranges resulted from the addition of pads after different intervals during storage (fig. 6). Oranges with biphenyl pads present during the final 2 weeks' storage at 70° F. absorbed 61 p.p.m. biphenyl, whereas those with biphenyl pads present during the entire storage of 3 days at 70° plus 3 weeks at 42° plus 2 weeks at 70° absorbed 63 p.p.m. biphenyl. Oranges absorbed 32 percent of the biphenyl that volatilized from the pads during 3 weeks at 42° plus 2 weeks at 70° and 27 percent during 2 weeks at 70°.

Oranges held in cartons without biphenyl pads for 3 days at 70° F. plus 3 weeks at 42° plus 2 weeks at 70° together with cartons of biphenyl-treated oranges absorbed 49 p.p.m. biphenyl, 78 percent of the quantity absorbed by biphenyl-treated fruit. Treated oranges continued to absorb biphenyl from the atmosphere of the storage room after the pads were removed. The absorption of biphenyl from the atmosphere of the storage room also occurred with the use of aluminum foil barriers where the oranges absorbed more biphenyl than that volatilized from the pads. Rajzman (*8*) found that citrus fruit in plain wraps stored in the same room with fruit in biphenyl wraps absorbed 50 percent of the quantity absorbed by biphenyl-treated fruit. Hayward (*3*) also found a gradual absorption of biphenyl by untreated oranges stored in the same room with biphenyl-treated oranges.

Series C Tests

Polyethylene-wrapped fruit.—Oranges stored without biphenyl with polykraft paper between layers or individually wrapped in polyethylene film comprised this series.

Series D Tests

Effect of different levels of inoculated fruit and of carton venting on biphenyl absorption during storage for 2 weeks at 70° F.—Standard vented and nonvented cartons of Valencia oranges contained 0, 5, 10, and 15 percent inoculated fruit during 2 weeks' storage at 70° F. Two pads, one placed between the first and second and one between the fourth and fifth layers of fruit, contained 2.38 grams biphenyl each. Oranges in vented cartons absorbed 91, 92, 85, and 89 p.p.m. biphenyl, and those in nonvented cartons absorbed 106, 113, 113, and 112 p.p.m. biphenyl in cartons containing

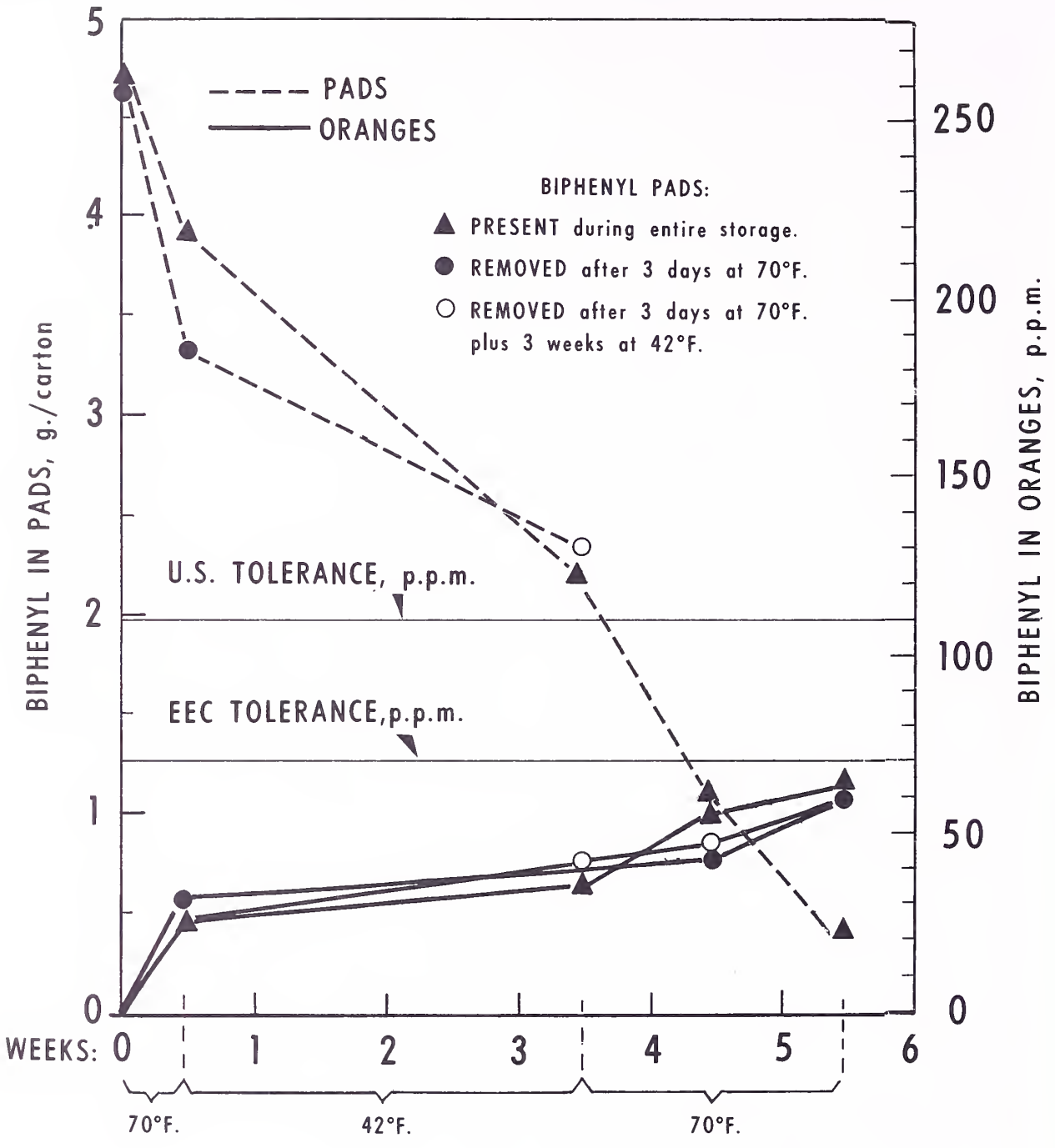

FIGURE 5.—Depletion of biphenyl pads and biphenyl absorption by Valencia oranges with removal of the biphenyl pads after different intervals during storage. Each carton contained two pads with 2.38 grams biphenyl each.

0, 5, 10, and 15 percent decayed fruit, respectively. These results indicate that the amount of decay present in the carton does not affect the amount of biphenyl absorbed by sound fruit. Duplicate analyses of decayed oranges from three of the vented cartons showed that decayed oranges absorbed 200

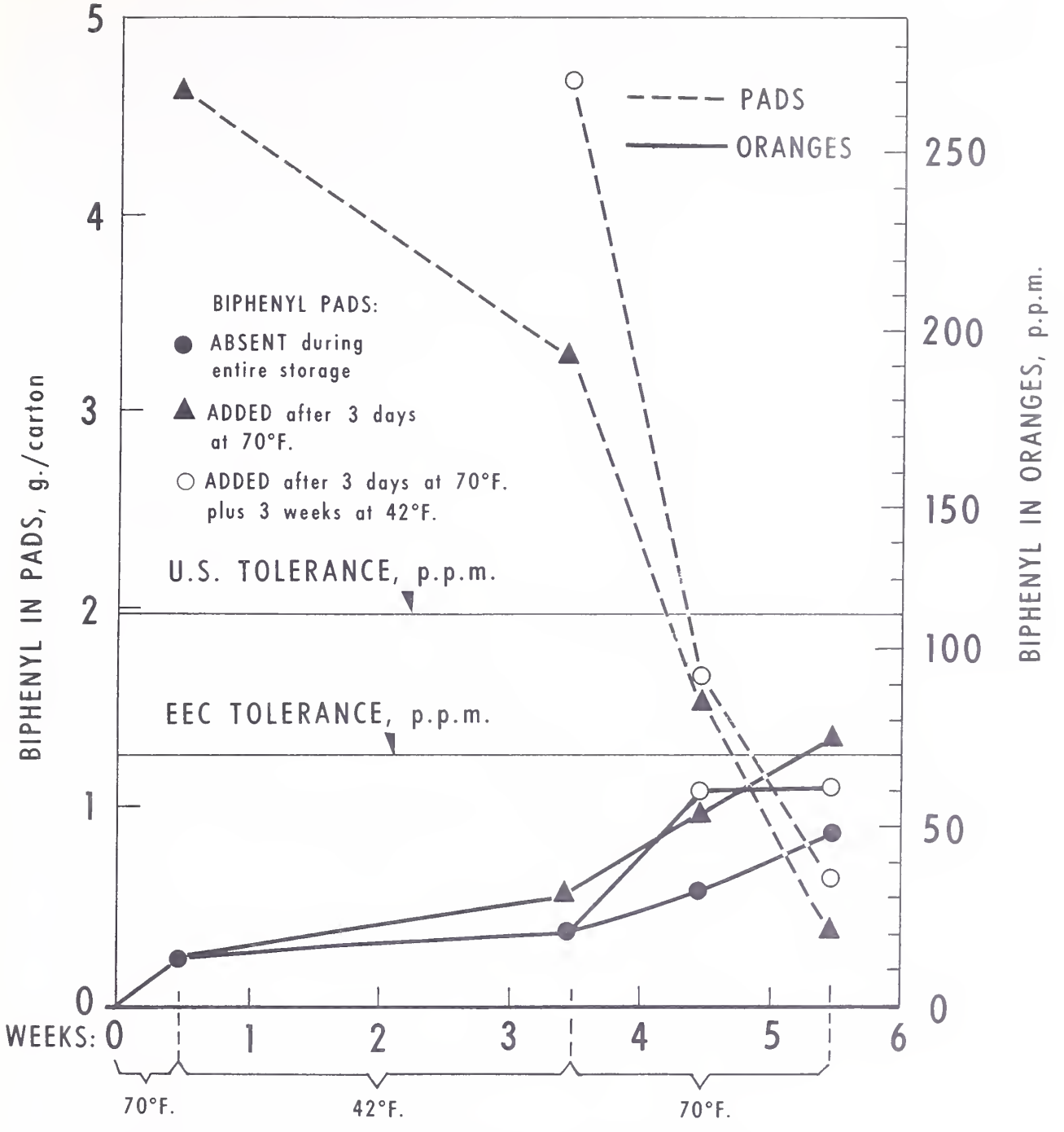

FIGURE 6.—Depletion of biphenyl pads and biphenyl absorption by Valencia oranges with addition of biphenyl pads after different intervals during storage. Each carton contained two pads with 2.38 grams biphenyl per pad.

p.p.m. biphenyl on a fresh fruit basis compared with an average of 91 p.p.m. biphenyl absorbed by the sound fruit in the same cartons. Additional tests are required for conclusive evidence that decaying oranges absorb much more biphenyl than sound oranges.

Figure 7 depicts the average biphenyl absorption by these Valencia oranges during 2 weeks' storage at 70° F. in vented and nonvented cartons. The oranges in nonvented cartons exceeded both the U.S. and EEC tolerances, and those in vented cartons the EEC tolerance after 2 weeks' storage at 70°.

Oranges in vented cartons without biphenyl pads stored for 2 weeks at 70° F. in the same room with cartons of biphenyl-treated fruit absorbed 37 and 51 percent of the quantity of biphenyl absorbed by the biphenyl-treated oranges during 1 and 2 weeks, respectively. Oranges in nonvented cartons without biphenyl pads stored in the same room with cartons of biphenyl-treated fruit absorbed 12 and 16 percent of the quantity of biphenyl absorbed by the biphenyl-treated fruit during 1 and 2 weeks at 70°, respectively.

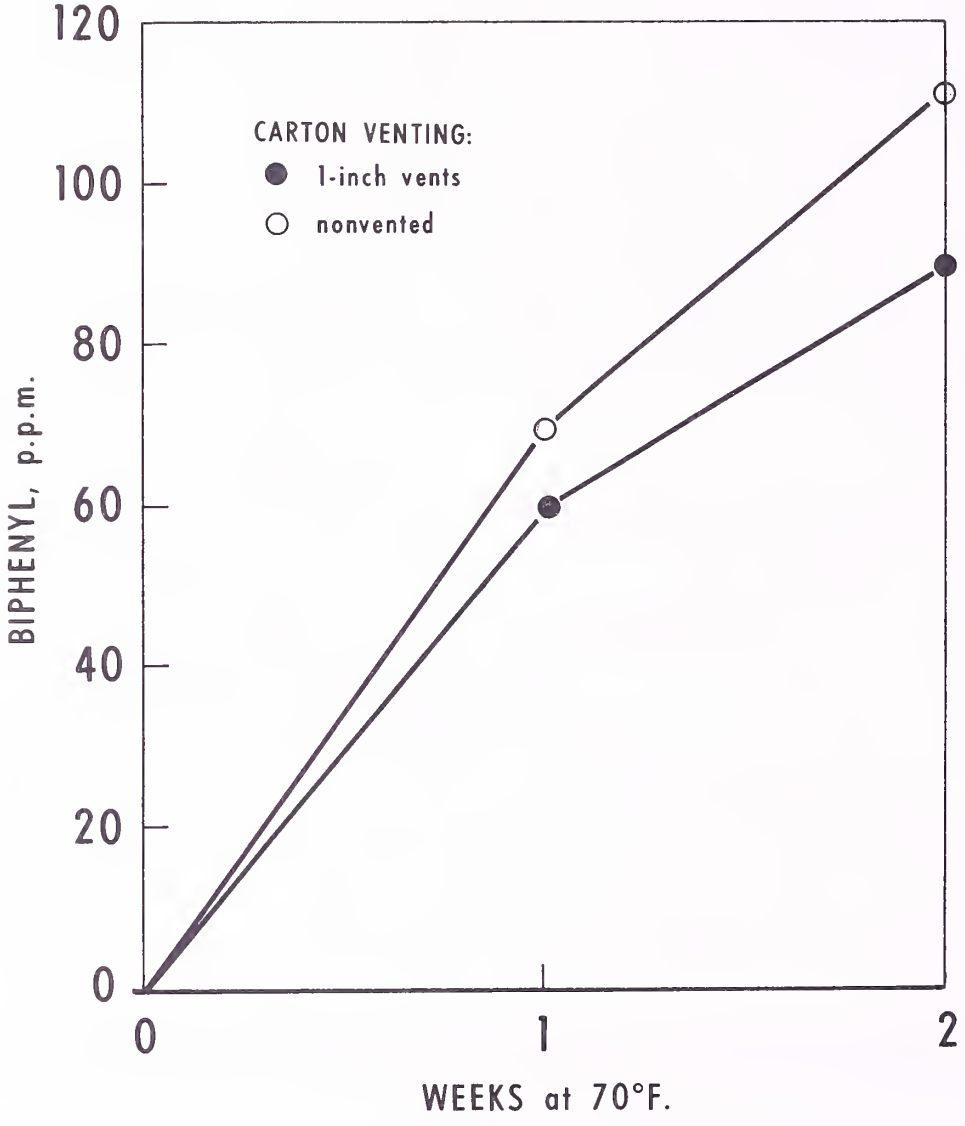

FIGURE 7.—Biphenyl absorption by Valencia oranges in vented and nonvented cartons held for 2 weeks at 70° F. with two pads (2.38 grams biphenyl each), one placed between the first and second and one between the fourth and fifth layers of fruit.

Decay and Soilage

Series A Tests

Different types of carton ventings, barriers, and biphenyl dosages during storage for 3 and 4 weeks at 50° F. plus 1 and 2 weeks at 70°.—Decay of navel oranges associated with carton venting, biphenyl dosages, and barriers ranged between 63 and 77 percent after 4 weeks' storage at 50° plus 2 weeks at 70° (table 1). Nonvented cartons of oranges with one pad (2.38 grams biphenyl), vented cartons with one pad (2.38 grams biphenyl) and polykraft and wax paper barriers, and vented cartons with one pad (1.38 grams biphenyl) contained the most decay; oranges in these cartons contained 82, 62, 56, and 56 p.p.m. biphenyl respectively. Oranges held in cartons with one pad (2.38 grams biphenyl) had intermediate decay and absorbed 59 p.p.m. biphenyl. Cartons with ½-inch vents and one pad (2.38 grams biphenyl) and cartons with 1-inch vents and two pads (2.38 grams biphenyl each) contained the least amount of decay. Oranges in these cartons absorbed 65 and 82 p.p.m. biphenyl, respectively, at the end of storage. These results do not indicate a relationship between control of decay and the amount of biphenyl the fruit absorbs. Spores of *Penicillium* blue mold in the inoculum resulted in considerable contact decay; consequently, all decay was severe.

The effects of carton venting, biphenyl dosages, and barriers on soilage are shown in table 2. Without barriers, oranges in cartons with ½- and 1-inch vents and one standard pad and in cartons with 1-inch vents and two pads had the least amount of soilage at the end of storage; oranges in these treatments absorbed 59, 65, and 82 p.p.m. biphenyl, respectively. Generally, soilage in cartons with ½- and 1-inch vents and one pad was higher than in similar cartons with two pads. Treatments with polykraft and wax paper barriers with one standard pad and cartons with one pad (1.38 grams biphenyl) produced the most soilage; oranges in these treatments absorbed 62, 56, and 56 p.p.m. biphenyl, respectively. Cartons with 1-inch vents had 10 percent less fruit that was soiled than decayed, and cartons with ½-inch vents, 20 percent. Oranges in cartons containing two standard pads per carton had equal amounts of soilage and decay. Cartons with one pad (1.38 grams biphenyl) and all cartons with barriers and one standard pad contained more soiled than decayed fruit.

TABLE 1.—*Decay of navel oranges associated with carton venting, biphenyl dosages, and barriers placed between the fruit and the biphenyl pads* [1]*—by percent*

Biphenyl treatment and kind of carton	Percentage of oranges decayed after—					
	3 weeks' storage at 50° F.			4 weeks' storage at 50° F.		
	Only	Plus 1 week at 70°	Plus 2 weeks at 70°	Only	Plus 1 week at 70°	Plus 2 weeks at 70°
1 1.38 g. biphenyl pad in carton with 1-in. vents and no barriers				16	----------	75
1 2.38 g. biphenyl pad in carton—						
Without vents or barriers				15	----------	74
With 1-in. vents and—						
No barriers	9	36	65	13	43	68
Polykraft paper barriers				12	----------	75
Aluminum foil barriers				12	----------	66
Wax paper barriers				16	----------	77
With ½-in. vents and no barriers	12	31	65	19	51	63
2 2.38 g. biphenyl pads in carton with 1-in. vents and no barriers	7	25	45	15	42	65

[1] Each value represents the average of 3 cartons and includes 7 percent inoculated fruit (*Penicillium* green and blue molds) placed in each carton during packing.

TABLE 2.—*Soilage of navel oranges associated with carton venting, biphenyl dosages, and barriers placed between the fruit and the biphenyl pads*[1]*—by percent*

Biphenyl treatment and kind of carton	Percentage of oranges soiled after—					
	3 weeks' storage at 50° F.			4 weeks' storage at 50° F.		
	Only	Plus 1 week at 70°	Plus 2 weeks at 70°	Only	Plus 1 week at 70°	Plus 2 weeks at 70°
1 1.38 g. biphenyl pad in carton with 1-in. vents and no barriers				27	----------	97
1 2.38 g. biphenyl pad in carton—						
Without vents or barriers				27	----------	70
With 1-in. vents and—						
No barriers	24	33	64	30	24	54
Polykraft paper barriers				33	----------	83
Aluminum foil barriers				39	----------	72
Wax paper barriers				44	----------	83
With ½-in. vents and no barriers	25	28	70	26	30	44
2 2.38 g. biphenyl pads in carton with 1-in. vents and no barriers	12	20	20	19	18	63

[1] Each value represents the average of 3 cartons. Percentage of soilage is calculated on the basis of sound fruit.

Series B Tests

Addition and removal of biphenyl pads at different intervals during storage for 3 days at 70° F. plus 3 weeks at 42° plus 1 and 2 weeks at 70°.—Decay associated with addition and removal of biphenyl after different intervals during storage is shown in table 3. Decay increased 17 percent in fruit stored without biphenyl pads compared with biphenyl-treated fruit. Decay was slightly higher in oranges with biphenyl pads added after 3 days at 70° than in those with biphenyl pads present during the entire storage. Decay was slightly higher in oranges with biphenyl pads present during 3 days at 70° plus 3 weeks at 42° and removed the last 2 weeks at 70° than in those with biphenyl pads present during 3 weeks at 42° plus 2 weeks at 70°. The amount of decay was about the same with pads present 3 days at 70° plus 3 weeks at 42° as with pads present 3 weeks at 42° plus 2 weeks at 70°. Biphenyl pads present only during the first 3 days at 70° or only during the final 2 weeks at 70° did not control decay. These results indicate that biphenyl should be present during the early stages of decay and remain in the cartons for best control.

Soilage generally increased in cartons with biphenyl pads present only during part of the storage (table 4). Cartons without biphenyl pads contained nearly three times as much soiled fruit and cartons with biphenyl pads present only during the first 3 days at 70° F. contained twice as much soiled fruit as those with biphenyl pads present during the entire storage. Soilage was slightly higher when biphenyl pads were added after the first 3 days at 70° than when the pads were present the entire storage. Oranges held without biphenyl had the most soilage. Soilage was reduced somewhat when biphenyl pads were present only the first 3 days at 70°, when present only 3 days at 70° plus 3 weeks at 42°, and when present only during the final 2 weeks at 70°, compared with oranges held without biphenyl pads.

Oranges held the entire storage with biphenyl had equal amounts of soilage and decay, whereas oranges held without biphenyl had 38 percent more soilage than decay (tables 3 and 4). Adding and removing pads during storage resulted in 14 percent more soilage than decay for all treatments except when biphenyl pads were added after 3 days' storage at 70°; these oranges had slightly less soilage than decay.

Series C Tests

Polyethylene-wrapped oranges held for 3 days at 70° F. plus 3 weeks at 42° plus 1 and 2 weeks at 70°.—Valencia oranges individually wrapped in polyethylene film and held without biphenyl pads had 16 percent decay after 3 days at 70° F. plus 3 weeks at 42°, 20 percent decay after 3 days at

TABLE 3.—*Decay of Valencia oranges associated with addition and removal of standard biphenyl pads after different intervals during storage* [1]*—by percent*

Treatment	Length and temperatures (°F.) of storage			
	3 da. @70°	3 da. @70° 3 wk. @42°	3 da. @70° 3 wk. @42° 1 wk. @70°	3 da. @70° 3 wk. @42° 2 wk. @70°
No biphenyl pads	6.3	14	27	50
Biphenyl 3 da. @70°, then removed	6.7	----------	21	46
Biphenyl 3 da. @70° and 3 wk. @42°, then removed	6.7	10	20	38
Biphenyl during entire storage	4.6	10	19	30
Biphenyl added after 3 da. @70° plus 3 wk. @42°	6.3	14	46	57
Biphenyl added after 3 da. @ 70°	6.3	10	20	36

[1] Each value represents the average of 3 cartons and includes 3.5 percent inoculated fruit (*Penicillium* green mold) placed in each carton during packing.

70° plus 3 weeks at 42° plus 1 week at 70°, and 31 percent decay after 3 days at 70° plus 3 weeks at 42° plus 2 weeks at 70°. The amount of decay was comparable to biphenyl-treated fruit for the same storage period. Decay did not develop from contact with decaying fruit in the cartons. The fruit, individually wrapped in polyethylene, had a sour odor which permeated the entire carton, and the type of decay was different from that of unwrapped fruit. The polyethylene film clung to the fruit and the growth of the decay organisms was different in these areas. These results warrant

TABLE 4.—*Soilage of Valencia oranges associated with addition and removal of standard biphenyl pads after different intervals during storage* [1]*—by percent*

Treatment	Length and temperatures (°F.) of storage			
	3 da. @70°	3 da. @70° 3 wk. @42°	3 da. @70° 3 wk. @42° 1 wk. @70°	3 da. @70° 3 wk. @42° 2 wk. @70°
No biphenyl pads	0.3	26	38	88
Biphenyl 3 da. @70°, then removed	.5	----------	28	61
Biphenyl 3 da. @70° plus 3 wk. @42°, then removed	.5	4	22	52
Biphenyl during entire storage	0	5	20	30
Biphenyl added after 3 da. @70° plus 3 wk. @42°	.3	26	63	70
Biphenyl added after 3 da. @70°	.3	14	18	31

[1] Each value represents the average of 3 cartons. Percentage of soilage is calculated on the basis of sound fruit.

further studies with other types of wrapping materials.

No soilage occurred in these tests.

Polykraft paper between layers of fruit held 3 days at 70° F. plus 3 weeks at 42° plus 1 and 2 weeks at 70°.—Valencia oranges held without biphenyl pads but with polykraft paper between layers of fruit had 11 percent decay after 3 days at 70° F. plus 3 weeks at 42°, 23 percent decay after 3 days at 70° plus 3 weeks at 42° plus 1 week at 70°, and 52 percent decay after 3 days at 70° plus 3 weeks at 42° plus 2 weeks at 70°. The amount of decay was comparable to storage without biphenyl pads and without paper between layers during the same storage period and temperatures.

Valencia oranges had 22 percent soilage after 3 days at 70° F. plus 3 weeks at 42°, 29 percent soilage after 3 days at 70° plus 3 weeks at 42° plus 1 week at 70°, and 55 percent soilage after 3 days at 70° plus 3 weeks at 42° plus 2 weeks at 70°. The amount of soilage was 23 percent less than that in oranges held without biphenyl pads and without paper between layers during the same storage periods and temperatures. Polykraft papers between layers tended to act as reservoirs for moisture.

Series D Tests

Different levels of inoculated fruit in cartons of Valencia oranges held 1 and 2 weeks at 70° F.—After 2 weeks at 70° F., vented cartons contained 14, 19, 21, and 24 percent decay and nonvented cartons contained 15, 13, 22, and 24 percent decay when 0, 5, 10, and 15 percent inoculated fruit, respectively, were added to the cartons before storage. Vented and nonvented cartons without inoculated fruit and without biphenyl pads stored in the same room with the biphenyl-treated fruit contained 12 percent decay after 2 weeks at 70°.

After 2 weeks at 70° F., vented cartons contained 20, 12, 15, and 14 percent soiled fruit and nonvented cartons contained 6, 9, 6, and 7 percent soiled fruit when 0, 5, 10, and 15 percent inoculated fruit, respectively, were added to the cartons before storage. Vented cartons without inoculated fruit and without biphenyl pads stored in the same room with the biphenyl-treated fruit contained 36 percent soiled fruit, and nonvented cartons under the same conditions contained 47 percent.

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