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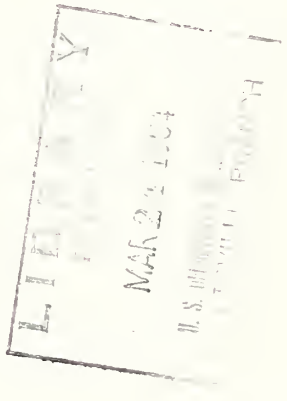
Biphenyl Control of CITRUS Spoilage

Influence of Time, Temperature, and Carton Venting



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BIPHENYL CONTROL OF CITRUS SPOILAGE
Influence of Time, Temperature, and Carton Venting

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SUMMARY

When biphenyl was properly used, simulated shipping tests showed that residues in oranges, grapefruit, and mandarins were less than the legal tolerances for the United States and European countries.

Because there is concern in the United States and in some European countries about additives to food, research was done on biphenyl residues in citrus. Biphenyl and refrigeration are used by most packers to control decay in citrus during long shipments. This report gives information on how decay of citrus can be controlled without excessive residue remaining in the fruit.

In the tests described in this report, commercial sheets of kraft paper, 10 9/16 by 16 1/4 inches, impregnated with biphenyl at the rate of 4 pounds per 1,000 square feet, were packed top and bottom in standard vented and nonvented cartons.

For simulated domestic shipments biphenyl-treated oranges held 1 week at 40° or 48° F. and then 1 week at 68° were about equally good but those held at 56° the first week had considerably more spoilage. Oranges in nonvented cartons with biphenyl were usually in much better condition than those in vented cartons. If biphenyl was not used, the oranges held initially at 40° were considerably cleaner than those held initially at 48°.

In tests simulating overseas shipments all oranges held 4 weeks at 40° F. were strikingly superior to those held at higher temperatures regardless of biphenyl or carton venting. Even the oranges in nonvented cartons with biphenyl pads at this temperature had a residue that was only one-half the European legal tolerance at a time corresponding to arrival at the European harbor. These oranges, if provided with refrigerated facilities during distribution to the consumer, would readily comply with present biphenyl tolerances. Biphenyl would reduce spoilage during the period of distribution, and its effectiveness would be greater in nonvented than in vented cartons.

Oranges deteriorated much more rapidly at a "transit" temperature of 48° F. than at 40°, and still more rapidly at 56°. A temperature only slightly warmer is suggested for oranges that may suffer chilling injury at 40°, to take advantage of the great benefits resulting from the reduced rate of fungal growth at the lowest temperature tolerated by the fruit. This practice also will cause the fruit to retain more of the original flavor and aroma than it would at higher temperatures.

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Lemons absorb less biphenyl than the other citrus fruits, and the results suggest that lemon cartons packed with biphenyl pads at the top and bottom may be shipped overseas in tight wooden shipping containers without the biphenyl content of the lemons exceeding present European or United States legal tolerances.

Grapefruit condition was maintained best in nonvented cartons with biphenyl in both simulated domestic and simulated overseas shipments. The biphenyl content remained within present legal tolerances.

Mandarins may absorb biphenyl more rapidly than oranges. The test results suggest that domestic shipments may be made in vented or nonvented cartons with the customary two biphenyl pads per carton. More tests are required to establish a safe practice for overseas shipments.

INTRODUCTION

European--particularly West German--as well as domestic markets are concerned with additives to foods. One of the issues raised concerns the question of biphenyl residues on American-grown citrus fruit. This report supplements previous research[2] in giving information on how control of decay can be accomplished effectively without excessive biphenyl accumulating in the fruit. This research is part of a broad continuing program by the Agricultural Marketing Service to maintain quality and to reduce spoilage losses in farm products.

The effects of temperature, storage time, carton venting, and kind of fruit on the rate of loss of biphenyl from the biphenyl pads and on the concentration of biphenyl vapor in the carton atmosphere, and the relationship of these factors to decay, sporulation, and soilage (dusting of sound fruit with spores of fungi from decaying fruit) of the fruit were determined.

Studies on the use of biphenyl for reducing decay and soilage of citrus fruits are needed to improve the condition of these fruits on arrival at distant markets. Such studies have been made on lemons (MRR-569). This report gives results on similar experiments conducted with Valencia and Washington navel oranges, Ruby Red grapefruit, and Kara mandarins.

MATERIALS AND METHODS

Tests for Decay

The Valencia and Washington navel oranges used in the tests were grown at Claremont, Calif.; the grapefruit at Thermal, Calif.; and the mandarins at Highgrove, Calif. Twenty-five oranges and 15 grapefruit per carton were inoculated with a biphenyl-sensitive strain of Penicillium digitatum by the method previously used on lemons (MRR-569). The inoculated fruits were distributed among the 110 noninoculated oranges or 33 noninoculated grapefruit contained in each carton. Only three cartons of mandarins were used and none of the fruit was inoculated.

One-half of the oranges and grapefruit were packed in cartons vented with eighteen 1-inch holes, six on the top, six on the bottom, and three on each of two sides; the remainder was packed in nonvented cartons. One-half of the vented and one-half of the nonvented cartons of fruit were each provided with two biphenyl pads, one under and one over the fruit. The fruit was brought to storage temperature before it was inoculated and treated with biphenyl.

[2] Rygg, G. L., Wells, A. W., Norman, Shirley M., and Atrops, E. P. Biphenyl Control of Lemon Spoilage--Influence of Time, Temperature, and Carton Venting. U. S. Dept. Agr., Mktg. Res. Rpt. 569, 15 pp., illus., Dec. 1962. This report will be referred to as MRR-569.

The biphenyl pads consisted of biphenyl-impregnated kraft paper 10 9/16 by 16 1/4 inches. According to the manufacturer, 16.67 percent of the total weight was biphenyl, which was applied at the rate of 4 pounds per 1,000 square feet.

Two tests each were conducted with Valencia and Washington navel oranges, one with Marsh seedless grapefruit, and one with Kara mandarins. The Valencias in the first test were stored at 40°, 48°, and 56° F., but those in the second test were stored only at 40°. The navel oranges in both tests were stored at 40° and 48°, the grapefruit at 56°, and the mandarins at 38°. Orange and grapefruit storage was continued for 1 week to simulate shipment to domestic markets and 4 weeks to simulate shipment to western European markets.

All the oranges and grapefruit removed from cold storage after 1 week were transferred to 68° F. and held an additional week before they were examined. One-half of the fruit of each treatment that was stored 4 weeks was examined at the end of the storage period and the remainder transferred to 68° and held 1 week to simulate the period of distribution at the market. The fruit was inspected for decay, sporulation, and soilage, and measured for biphenyl content.

All the mandarin cartons were vented and were stored 1 week at 38° F. One carton was sampled immediately after it was removed from storage; the second was held 1 day at 68° before the sample was taken, each layer forming a separate sample; the third carton was held 1 day at 68° after it was removed from storage; one randomized sample was then removed from the carton and prepared for biphenyl analysis at once and the remaining fruit was aired on a tray 2 days at 68° before it was analyzed.

Thirty oranges, 20 grapefruit, and 50 mandarins per carton were used for measuring absorbed biphenyl. The two biphenyl pads in each carton were analyzed separately to measure the residual biphenyl. Three biphenyl-treated cartons of oranges and grapefruit and one of mandarins were used at each inspection. One carton each of oranges and grapefruit without biphenyl were analyzed; mandarins without biphenyl were not included.

One experiment was conducted to learn to what extent the amount of biphenyl absorbed was influenced by holding fruit in tight containers. Nonvented cartons of lemons were packed in the usual way with two biphenyl sheets per carton. Two steel drums were filled to capacity with these cartons, each holding 3 cartons. Two rectangular wooden boxes were constructed so that three cartons completely filled them. The drums were closed with steel covers, and the boxes with gasketed wooden covers.

The four filled containers were stored 3 weeks at 56° F., after which time the cartons were removed from the larger containers and stored with lids on and the biphenyl sheets in place for 3 more days at 68°. Samples of fruit were then taken so as to represent all levels from top to bottom and analyzed for biphenyl content.

Biphenyl Retained in Fruit and Containers

Four cartons of Valencia oranges were used to obtain information on the escape of biphenyl from the fruit after it was removed from the cartons. These oranges were stored with the usual two biphenyl pads in nonvented cartons for 1 week at 56° F. After the week's storage, representative 30-fruit samples of oranges were drawn from each carton for biphenyl analysis. The remainder of the fruit was exposed to air at 68° in open trays without biphenyl. Another sample from each of the original cartons of fruit was prepared for biphenyl analysis after 1 week's airing and a third sample after 2 weeks.

A similar test was conducted on Kara mandarins but only one carton was used. This vented carton was stored 1 week at 38° F. and then 1 day at 68° with the carton closed and the biphenyl pads in place. One sample of fruit was taken for biphenyl analysis after the day at 68°; the remaining fruit was aired in open trays at 68° for 2 days and then analyzed for biphenyl.

The method used to measure the biphenyl in the pads and in the fruit of the first Valencia orange test was described by Gunther, Blinn, and Barkley.[3] For the second Valencia test and the navel orange, grapefruit, and mandarin tests the method was modified by using the chromatostrip procedure[4] to purify the biphenyl.

Measuring Biphenyl Vapor

Test cartons without inoculated fruit were used to measure the concentration of biphenyl vapor in the carton atmosphere. These test cartons provided cartons with fruit reasonably free from decay, so the test could be continued longer than would be possible if inoculated fruit were present in the cartons.

Biphenyl vapor concentration was measured in the atmospheres in vented and nonvented cartons of Valencia oranges and Eureka lemons stored in triplicate for periods up to 5 weeks at 68° F., 6 weeks at 50°, and 9 weeks at 40°, and in vented cartons of mandarins stored 1 week at 38°.

Air samples from cartons stored at 50° and 68° F. were taken alternately from two groups of three cartons to reduce the frequency of sampling each carton. This was done to minimize the effect of sampling upon the subsequent concentration. A third set of three cartons stored at each of these temperatures was sampled at the end of the experiment to find if the repeated removal of 1-liter samples of air reduced the concentration of biphenyl vapor below that present in cartons that had not been sampled previously.

Only one set of cartons stored at 40° F. was sampled regularly. An additional set was sampled only at the end of the experiment.

Samples of air were drawn directly into adsorption tubes placed so the open ends were near the center of the cartons. The biphenyl was removed from the air by adsorbing it on activated alumina. It was eluted with ethyl alcohol, transferred to a small volume of cyclohexane, and measured in a gas chromatograph equipped with a flame ionization detector.[5]

The method used for measuring biphenyl vapor in air was not sensitive enough to permit analyzing small samples from various locations in the carton. To obtain this information the biphenyl absorbed by oranges in different parts of the carton was measured separately. Eight nonvented cartons of oranges were used for this purpose. All were packed in the usual manner with one biphenyl pad under and one above the fruit. Four of the cartons were stacked so they were surrounded on all sides but one by other filled cartons (group A). The exposed side was one of the large vertical surfaces. The remaining four cartons were completely surrounded by full cartons (group B). These cartons were stored 8 days at 68° F.

The fruit in group A was sampled by taking rows lengthwise of the carton. The oranges in the corresponding rows in the four cartons were combined to form one analytical sample. The resulting data provided the basis for calculating the average biphenyl content by layers and by tiers.

The fruit in group B was sampled by combining all the fruit in one layer of one carton into one sample. The values for corresponding layers in each of the four cartons were averaged to give the biphenyl content of each layer.

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[3] Gunther, F. A., Blinn, R. C., and Barkley, J. H. Procedure for Routine Determination of Biphenyl and o-Phenylphenol on and in Citrus Fruit. Analyst 88: 36-42. 1963.

[4] Stanley, W. L., Vannier, S. H., and Gentili, B. A Modified Method for the Quantitative Estimation of Diphenyl in Citrus Fruits. Assoc. Off. Agr. Chem. Jour. 40(1): 282-286. 1957.

[5] Wells, A. W., Norman, Shirley M., and Atrops, E. P. Measuring Biphenyl Vapor. Gas Chromatography 1(9): 19-20. 1963.

These oranges were sampled by removing discs of peel 2.15 cm. in diameter from positions midway between the top and the side or midway between the bottom and the side. Care was taken to avoid fruit surfaces in contact with biphenyl pads, carton walls, or other fruit. Two sets of samples were taken from the bottom layer of fruit. One set represents the peel above the middle of the fruit and one set the peel below the middle. All fruit above the bottom layer was sampled only on the surface above the middle.

The biphenyl content of the peel is reported in μg. per cm.^{2} (micrograms per square centimeter) of peel. The figures are related to the average vapor concentrations in different parts of the cartons during the storage period although the actual concentration in quantity of biphenyl per liter of air can not be stated.

Calculating Spoilage

Decay and sporulation are expressed in index values. The values were derived by assigning a value of 0.1 to fruits with lesions or sporulation surfaces with an average diameter less than 0.75 inch, 0.5 to fruits with lesions or sporulating surfaces from 0.75 inch in diameter to one-half the surface of the fruit, and 1.0 to fruit with more than half the surface covered with lesions or sporulating fungal growth. The sum of the values for each fruit was divided by the number of inoculated fruits and multiplied by 100 to give the index.

RESULTS

Oranges

Loss of Biphenyl from Pads

The factors affecting the loss of biphenyl from the pads were the same as those given for lemons (MRR-569), namely, carton venting, location of pads in the cartons, time, and temperature, and in addition, kind of fruit. No observations were made with oranges on the change of rate with time as was done with lemons.

Biphenyl escaped faster from pads in vented cartons of fruit than from those in nonvented cartons. The effect of venting was similar to that reported for lemons, but the difference between vented and nonvented cartons was only half as large. In 4 weeks at 40° F. the pads in vented orange cartons lost twice as much biphenyl as those in nonvented cartons; at 48° the difference was 1.5 to 1, and at 56° only 1.2 to 1.

Biphenyl pads placed over the fruit lost biphenyl faster than those placed under the fruit, as in lemon cartons, but the difference was smaller (table 1). Instead of a 4-fold difference at 40° F. as with lemons, the rate with oranges was only 1.5 times as fast in the upper pads as in the lower. The difference diminished at higher temperatures, and at 56° it was only 1.5 times as fast with lemons and 1.2 times as fast with oranges. These results agree with those of Rajzman[6] who found that citrus wraps near the top of the package lost biphenyl faster than those placed lower. Pads at the top and bottom of closely stacked completely surrounded nonvented cartons lost biphenyl at nearly equal rates (table 2).

The effect of temperature on loss of biphenyl from pads in orange cartons was similar to that noted for lemon cartons. The loss at 48° F. in a 4-week period was 50 percent higher than the loss at 40°, and the loss at 56° was more than twice the loss at 40° (table 1). The loss in 1 week at 68° was about equal to the loss in 4 weeks at 40°.

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[6] Rajzman, Anna. The Effect of Storage and Airing Upon Diphenyl Residues in Diphenyl-wrapped Oranges. Israel Jour. Agr. Res. 11(2): 125-131. 1961.

Table 1.--Deterioration of oranges stored with and without biphenyl in vented and nonvented cartons[1]

Temperature (°F.), length of storage, and carton venting	Biphenyl content				Decay of inoculated fruit[2]		Sporulation of inoculated fruit[2]		Soilage of noninoculated fruit[2]	
	Pads[3]		Fruit	Air	With biphenyl	Without biphenyl	With biphenyl	Without biphenyl	With biphenyl	Without biphenyl
	Top	Bottom								
	Grams	Grams	P.p.m.	μg.per liter	Index	Index	Index	Index	Percent	Percent
40°:										
1 week plus 1 week at 68°										
Vented	1.0	1.4	42	---	58	91	29	65	2	19
Nonvented	1.4	1.7	58	---	55	96	12	81	1	10
4 weeks										
Vented	1.3	1.7	22	[4] 3.3	19	34	0	0	0	0
Nonvented	1.8	2.0	34	[4] 3.3	15	41	0	0	0	0
4 weeks plus 1 week at 68°										
Vented	.6	1.0	51	---	76	92	62	87	31	55
Nonvented	1.1	1.3	73	---	50	100	36	100	18	67
48°:										
1 week plus 1 week at 68°										
Vented	.8	1.3	48	---	60	89	26	76	5	28
Nonvented	1.5	1.5	53	---	48	96	7	93	2	43
4 weeks										
Vented	.8	1.5	39	[5] 5.8	58	87	39	76	12	34
Nonvented	1.5	1.6	53	[5] 7.5	45	87	18	85	2	50
4 weeks plus 1 week at 68°										
Vented	.2	.8	54	---	79	93	64	93	40	67
Nonvented	.8	1.0	86	---	55	94	34	94	11	85
56°:										
1 week plus 1 week at 68°										
Vented	.8	1.2	50	---	84	100	79	98	41	43
Nonvented	1.2	1.6	54	---	77	96	46	98	20	87
4 weeks										
Vented	.4	.7	63	---	97	100	96	100	65	87
Nonvented	.8	1.0	84	---	93	100	79	100	31	64
4 weeks plus 1 week at 68°										
Vented	.1	.2	56	---	100	100	100	100	98	91
Nonvented	.4	.4	119	---	100	100	100	100	37	93

[1] Except for biphenyl in air, each value with biphenyl is the average of 12 cartons at 40°, 9 at 48°, and 3 at 56°; without biphenyl, 4 cartons at 40°, 3 at 48°, and 1 at 56°. Each value for biphenyl in air is the average of 3 cartons. Each carton contained 25 inoculated and 110 noninoculated oranges. [2] Decay and sporulation indexes are described on page 9. [3] Average initial value 2.4 grams per pad. [4] By interpolation. [5] Value at 50° F.

Table 2.--Biphenyl in pads, fruit, and air in nonvented orange cartons stored 8 days at 68° F.

A - Cartons exposed to air channel on one side; B - Cartons completely surrounded by full cartons; four cartons per treatment.

Treatment	Pads						Fruit peel	Air
	Top			Bottom				
	Before storage	After storage	Loss	Before storage	After storage	Loss		
	Grams	Grams	Grams	Grams	Grams	Grams	μg./cm.²	μg./l.
A	1.3	0.6	0.7	1.4	0.7	0.7	23	16
B	1.4	.6	.8	1.4	.6	.8	24	16

Biphenyl usually escaped more rapidly from pads in orange cartons (table 1) than from pads in lemon cartons at the same temperature (MRR-569). The difference in vented cartons was small, but in nonvented cartons the average loss in orange cartons was 1.7 times as high as the loss in lemon cartons.

Biphenyl Vapor in Carton Atmosphere

The highest concentration of biphenyl vapor observed in orange cartons was 40.0 μg. (micrograms) per liter of air. This concentration was found in cartons held at 68° F. The highest concentration at 50° was 10.3 μg., and at 40° 6.5 μg. All these values were observed in nonvented cartons. The highest concentrations found in vented orange cartons were 26.1 μg. per liter at 68°, 8.1 μg. at 50°, and 5.5 μg. at 40°.

The concentration increased rapidly at 68° F. until it peaked in 2 days and then decreased at a fairly constant rate until it reached 1 to 2 μg. per liter 6 weeks after the beginning of the experiment.

The concentration at 50° F. rose less rapidly than at 68°, and peaked in 1 week in nonvented cartons and in 3 weeks in vented cartons. The concentration remained fairly constant in both vented and nonvented cartons between 1 and 5 weeks after the cartons were prepared. At 5 weeks the concentrations were about equal in cartons held at 50° and at 68°, and the concentrations after 7 weeks at 50° were about twice as high as after 6 weeks at 68°.

The concentration in cartons at 40° F. peaked in 1 week and then decreased slowly to one-half the maximum after 5 weeks' storage. The concentration after 9 weeks' storage at 40° was higher than after 6 weeks at 68°.

The vapor concentration in nonvented cartons at 68° F. was much higher than that in vented cartons until the biphenyl supply was nearly exhausted. The difference between concentrations in vented and nonvented cartons at 50° was much smaller than at 68°, and at 40° the difference was reduced to about 1 μg. per liter. Details of the vapor concentrations appear in figure 1.

Details of the average distribution of biphenyl vapor were learned indirectly by measuring the amount of biphenyl absorbed by orange peel at six levels and at various horizontal positions in nonvented cartons. Figure 2 shows the places where the samples of peel were taken and the amount of biphenyl found at each place.

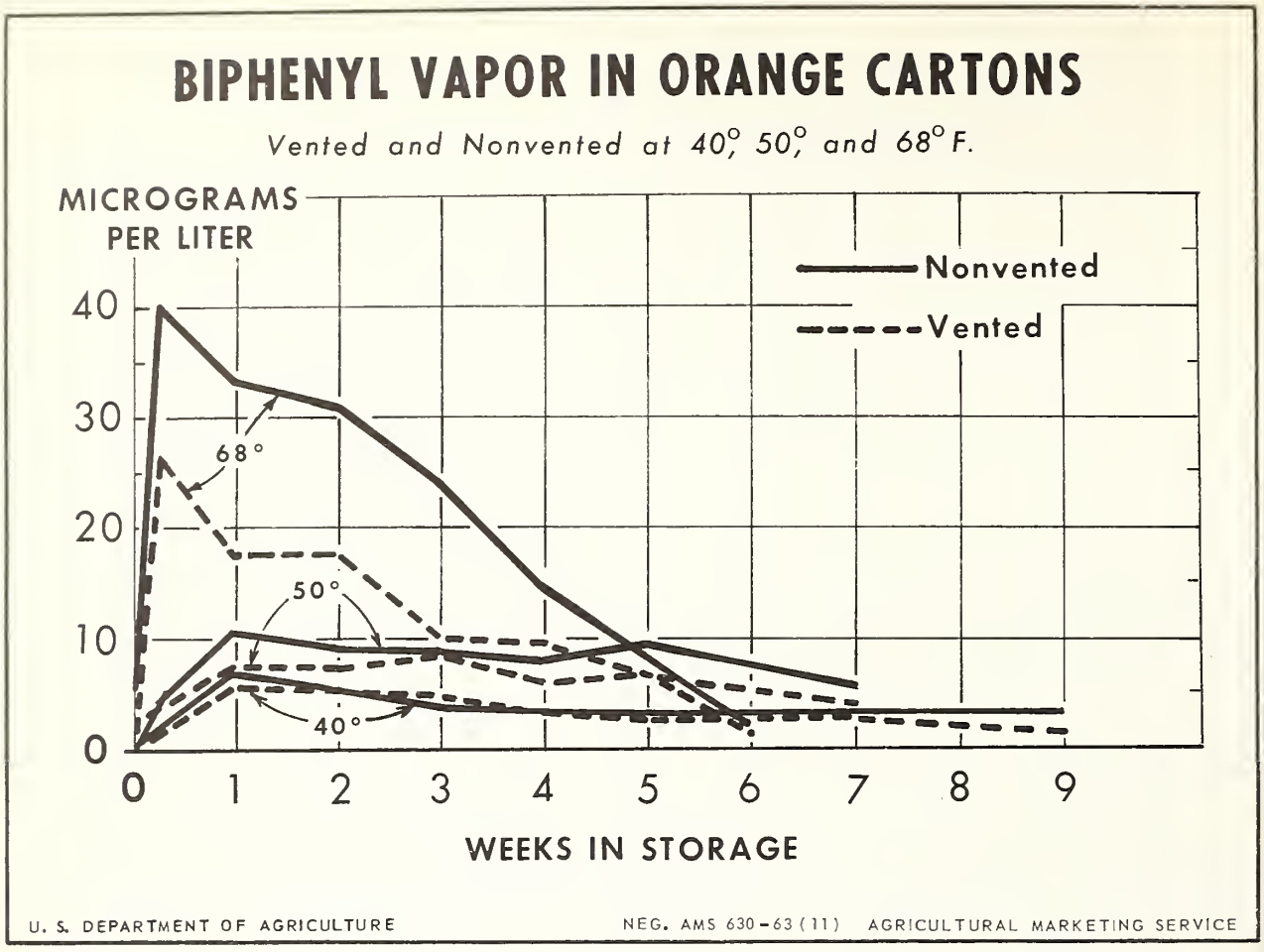

FIGURE 1

The peel on the lower side of the bottom layer of fruit had the highest biphenyl content with an average of 31 μg. per cm.^{2} in group A (cartons surrounded on all sides but one) and 35 μg. in group B (cartons completely surrounded by other full cartons). The peel on the upper side of fruit in the top layer absorbed only slightly less biphenyl, or 28 μg. per cm.^{2} in group A and 31 μg. in group B.

The amount of biphenyl absorbed by the peel of the fruit in the remaining layers, including the upper side of the bottom layer, was fairly uniform, and did not form a consistent pattern, either vertically or horizontally. Exposure of one carton wall to air did not produce a biphenyl absorption gradient, nor did exposure lower the average amount of biphenyl absorbed by the fruit or the average concentration of biphenyl vapor at the center of the cartons (fig. 2 and table 2).

These results suggest that the biphenyl vapor concentration is highest in the immediate vicinity of the biphenyl pads and that the concentration is quite uniform in the remainder of the carton. The results apply to closely stacked nonvented cartons with no more than one side exposed to an air channel. They can not be applied strictly to the tests reported below as many of the cartons used in those tests were vented, and they were not tightly surrounded by other full cartons.

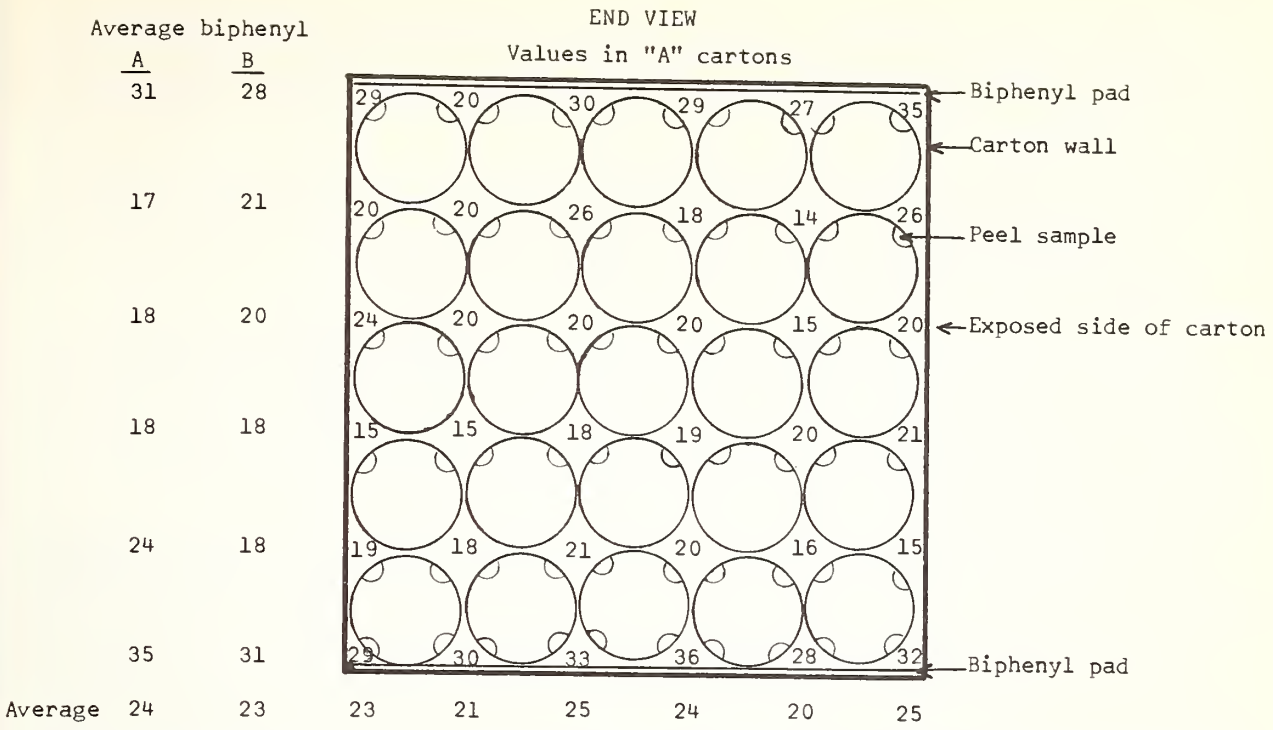

FIGURE 2. --Biphenyl in peel of oranges at various locations in nonvented cartons held 8 days at 68° F. A - cartons exposed to air channel on one side; B - cartons surrounded on all sides; 4 cartons per treatment; values are micrograms of biphenyl per square centimeter of peel.

Results with Stored Fruit

One week at 40° F. and 1 week at 68°. --Biphenyl pads placed over oranges in vented cartons stored 1 week at 40° F. and then held 1 week at 68° lost 57 percent of the original biphenyl and only 1 gram remained in each. Pads placed under the oranges lost 43 percent and 1.4 grams remained. The oranges in these cartons contained 42 p.p.m. biphenyl. One liter of air in similar cartons contained 5.5 μg. biphenyl vapor after 1 week at 40° (table 1 and fig. 1). Biphenyl vapor was not measured after combinations of storage temperatures such as 40° followed by 68°.

Inoculated oranges in vented cartons with biphenyl had a decay index of 58 and a sporulation index of 29; those in similar cartons without biphenyl had a decay index of 91 and a sporulation index of 65. Two percent of the noninoculated oranges in cartons with biphenyl and 19 percent of those in cartons without biphenyl were soiled by spores from decaying oranges.

Biphenyl pads placed over oranges in nonvented cartons stored 1 week at 40° F. and then held 1 week at 68° lost 39 percent of the original biphenyl and 1.4 grams remained in each. Those placed under the fruit lost 29 percent, and 1.7 grams remained. The oranges in these cartons contained 58 p.p.m. biphenyl. The air in similar cartons contained 6.5 μg. biphenyl vapor per liter after 1 week at 40° (fig. 1). Biphenyl vapor was not measured after the week's storage at 68°.

Inoculated oranges in cartons with biphenyl pads had a decay index of 55 and a sporulation index of 12; those in similar cartons without biphenyl had a decay index of 96 and a sporulation index of 81. Only 1 percent of the noninoculated fruit in cartons with biphenyl was soiled compared with 10 percent in similar cartons without biphenyl (table 1).

Oranges in nonvented cartons absorbed 38 percent more biphenyl than those in vented cartons, but the amount was still well below both United States and West German legal tolerances. The decay index was reduced only slightly by omitting carton venting, but the sporulation index and percent spoilage were reduced one-half by omitting venting of cartons with biphenyl.

Oranges in vented cartons without biphenyl had lower decay and sporulation indexes than those in nonvented cartons but the percentage of soilage was not lower.

Biphenyl substantially reduced decay index, sporulation index, and percent of soilage in both vented and nonvented cartons.

Four weeks at 40° F. --Biphenyl pads placed over oranges in vented cartons stored 4 weeks at 40° F. lost 45 percent of the original biphenyl and 1.3 grams remained in each. Pads placed under the fruit lost 28 percent and 1.7 grams remained. The oranges in these cartons contained 22 p.p.m. biphenyl. One liter of air in similar cartons contained 5.5 μg. biphenyl vapor after 1 week's storage, 4.6 μg. after 3 weeks, and by interpolation in figure 1, 3.3 μg. after 4 weeks.

Inoculated oranges in vented cartons with biphenyl had a decay index of 19, and those in similar cartons without biphenyl 34. No spores formed on oranges stored continuously at 40° F. for 4 weeks either with or without biphenyl; consequently the sporulation index was 0, and no fruit was soiled.

Biphenyl pads placed over oranges in nonvented cartons stored 4 weeks at 40° F. lost 24 percent of the original biphenyl and 1.8 grams remained in each. Pads placed under the fruit lost 15 percent and 2.0 grams remained. The oranges in these cartons contained 34 p.p.m. biphenyl. One liter of air in similar cartons contained 6.5 μg. biphenyl vapor after 1 week's storage, 3.6 μg. after 3 weeks, and by interpolation, 3.3 μg. after 4 weeks (table 1 and fig. 1).

Inoculated oranges in nonvented cartons with biphenyl had a decay index of 15 and those in similar cartons without biphenyl 41. No sporulation or soilage appeared on fruit stored 4 weeks at 40° whether or not biphenyl was used; the low temperature prevented spore formation (table 1).

Oranges in nonvented cartons absorbed 54 percent more biphenyl than those in vented cartons, but the biphenyl content was still well below both the United States and West German tolerances. The conditions of this test are close to the optimum transit conditions for oranges en route to European markets. The decay index of fruit in nonvented cartons supplied with biphenyl was slightly lower than that in vented cartons but the index in nonvented cartons without biphenyl was slightly higher. All oranges stored 4 weeks at 40° were free from sporulation and soilage without regard to carton venting or biphenyl treatment.

Four weeks at 40° F. and 1 week at 68°. --Biphenyl pads placed over oranges in vented cartons stored 4 weeks at 40° F. and then 1 week at 68° lost 76 percent of the initial biphenyl and 0.6 gram remained in each. Pads placed under the fruit lost 58 percent and 1.0 gram remained. The oranges in these cartons contained 51 p.p.m. biphenyl. Biphenyl vapor was not measured after the cartons were transferred to 68°.

Inoculated oranges in vented cartons with biphenyl had a decay index of 76 and a sporulation index of 62; those in similar cartons without biphenyl had a decay index of 92 and a sporulation index of 87. Thirty-one percent of the noninoculated fruit in cartons with biphenyl and 55 percent of those in cartons without biphenyl were soiled.

Biphenyl pads placed over oranges in nonvented cartons stored 4 weeks at 40° F. and then 1 week at 68° lost 55 percent of the initial biphenyl and 1.1 grams remained in each. Pads placed under the fruit lost 47 percent and 1.3 grams remained. The oranges in these cartons contained 73 p.p.m. biphenyl. The value is slightly higher than the

present legal tolerance of 70 p.p.m. in West Germany. A biphenyl content as high as this could be reached if oranges shipped with biphenyl pads in nonvented cartons were held as long as 1 week at a temperature as high as 68° in a poorly ventilated space after they were unloaded from a ship. Refrigerated storage and transit facilities should enable shippers and receivers to avoid having oranges exceed the tolerance.

Inoculated oranges in nonvented cartons with biphenyl had a decay index of 50 and a sporulation index of 36; those in similar cartons without biphenyl had decay and sporulation indexes of 100. Eighteen percent of the noninoculated oranges in cartons with biphenyl and 67 percent of those in cartons without biphenyl were soiled (table 1).

Oranges in nonvented cartons absorbed 43 percent more biphenyl than those in vented cartons. The decay index of oranges in vented cartons with biphenyl was 50 percent higher than that of fruit in nonvented cartons, the sporulation index 72 percent higher, and soilage 72 percent higher. These results emphasize the desirability of using nonvented cartons for export oranges if the biphenyl content can be kept below the legal tolerance. Oranges that are likely to suffer from chilling injury when held at 40° F. during the 4-week transit period should be held at 42°.

One week at 48° F. and 1 week at 68°. --Biphenyl pads placed over oranges in vented cartons stored 1 week at 48° F. and then held 1 week at 68° lost 66 percent of the original biphenyl and 0.8 gram remained. Pads placed under the fruit lost 45 percent and 1.3 grams remained. Oranges in these cartons contained 48 p.p.m. biphenyl. Biphenyl vapor in cartons stored at 48° was not measured, but after 1 week at 50° the air in vented orange cartons contained 7.3 μg. biphenyl vapor per liter (table 1 and fig. 1).

Inoculated oranges in vented cartons with biphenyl had a decay index of 60 and a sporulation index of 26; those in similar cartons without biphenyl had a decay index of 89 and a sporulation index of 76. Five percent of the noninoculated oranges in vented cartons with biphenyl and 28 percent of those in similar cartons without biphenyl were soiled.

Biphenyl pads placed over oranges in nonvented cartons stored 1 week at 48° F. and then held 1 week at 68° lost 37 percent of the original biphenyl and 1.5 grams remained. Pads placed under the fruit lost 35 percent and 1.5 grams remained. The oranges in these cartons contained 53 p.p.m. biphenyl. Biphenyl vapor in cartons stored at 48° was not measured, but after 1 week at 50° the air in nonvented cartons contained 10.3 μg. biphenyl per liter of air (table 1 and fig. 1).

Inoculated oranges in nonvented cartons with biphenyl had a decay index of 48 and a sporulation index of 7; those in similar cartons without biphenyl had a decay index of 96 and a sporulation index of 93. Two percent of the noninoculated oranges in nonvented cartons with biphenyl and 43 percent of those in similar cartons without biphenyl were soiled (table 1).

Oranges in nonvented cartons absorbed only 10 percent more biphenyl than those in vented cartons and the biphenyl content of all these oranges was far below present legal tolerance. The decay index of oranges in vented cartons with biphenyl was 25 percent higher than that of fruit in nonvented cartons, the sporulation index 3.7 times as high, and soilage 2.5 times as high. Neither lot of fruit was badly soiled. These results again emphasize the value of nonvented cartons when used in conjunction with biphenyl. On the other hand, without biphenyl, fruit in vented cartons had less decay, sporulation, and soilage than fruit in nonvented cartons.

Four weeks at 48° F. --Biphenyl pads placed over oranges in vented cartons stored 4 weeks at 48° F. lost 64 percent of the original biphenyl and 0.8 gram remained in each. Pads placed under the fruit lost 38 percent and 1.5 grams remained. Oranges in these cartons contained 39 p.p.m. biphenyl. The concentration of biphenyl vapor in similar cartons stored at 50° reached a maximum of 8.1 μg. per liter of air in 3 weeks and dropped to 5.8 μg. in 4 weeks (table 1 and fig. 1).

Inoculated oranges in vented cartons with biphenyl had a decay index of 58 and a sporulation index of 39; those in similar cartons without biphenyl had a decay index of 87 and a sporulation index of 76. Twelve percent of the noninoculated oranges in cartons with biphenyl and 34 percent of the fruit in cartons without biphenyl were soiled.

Biphenyl pads placed over oranges in nonvented cartons stored 4 weeks at 48° F. lost 34 percent of the original biphenyl and 1.5 grams remained in each. Pads placed under the fruit lost 32 percent and 1.6 grams remained. Oranges in these cartons contained 53 p.p.m. biphenyl. The concentration of biphenyl vapor in similar cartons stored at 50° F. reached a maximum of 10.3 μg. per liter of air in 1 week and fell to 7.5 μg. at the end of 4 weeks (table 1 and fig. 1).

Inoculated oranges in nonvented cartons with biphenyl had a decay index of 45 and a sporulation index of 18; those in similar cartons had a decay index of 87 and a sporulation index of 85. Two percent of the noninoculated oranges in cartons with biphenyl and 50 percent of the fruit in cartons without biphenyl were soiled (table 1).

Oranges in nonvented cartons absorbed 36 percent more biphenyl than those in vented cartons but all were within present legal tolerances. The decay index of oranges in vented cartons with biphenyl was 29 percent higher than that of fruit in nonvented cartons, the sporulation index was more than twice as high, and percent soilage 6 times as high. The advantage of nonvented cartons at this temperature when biphenyl is used is clear. However, oranges packed without biphenyl fared better in vented cartons.

Four weeks at 48° F. and 1 week at 68°. --Biphenyl pads placed over oranges in vented cartons stored 4 weeks at 48° F. and then held 1 week at 68° lost 90 percent of the original biphenyl, and 0.2 gram remained in each. Pads placed under the fruit lost 68 percent and 0.8 gram remained. Oranges in these cartons contained 54 p.p.m. biphenyl.

Inoculated oranges in vented cartons with biphenyl had a decay index of 79 and a sporulation index of 64; those in similar cartons without biphenyl had decay and sporulation indexes of 93. Forty percent of the noninoculated oranges in cartons with biphenyl and 67 percent of those in cartons without biphenyl were soiled.

Biphenyl pads placed over oranges in nonvented cartons stored 4 weeks at 48° F. and then held 1 week at 68° lost 66 percent of the original biphenyl and 0.8 gram remained in each. Pads placed under the fruit lost 56 percent and 1.0 gram remained. Oranges in these cartons contained 86 p.p.m. biphenyl.

Inoculated oranges in nonvented cartons with biphenyl had a decay index of 55 and a sporulation index of 34; those in similar cartons without biphenyl had decay and sporulation indexes of 94. Eleven percent of the noninoculated oranges in cartons with biphenyl and 85 percent of those in cartons without biphenyl were soiled (table 1).

Oranges in nonvented cartons absorbed nearly 60 percent more biphenyl than those in vented cartons and the biphenyl content exceeded the present tolerance in West Germany. Although sporulation and soilage of oranges in nonvented cartons with biphenyl were lower than in vented cartons, the high biphenyl content of the fruit makes the use of nonvented cartons at this temperature objectionable. Furthermore, the fruit deteriorated excessively at this temperature in both vented and nonvented cartons, especially where biphenyl was not used.

One week at 56° F. and 1 week at 68°. --Biphenyl pads placed over oranges in vented cartons stored 1 week at 56° F. and then held 1 week at 68° lost 66 percent of the original biphenyl and 0.8 gram remained in each. Pads placed under the fruit lost 50 percent and 1.2 grams remained. Oranges in these cartons contained 50 p.p.m. biphenyl. Biphenyl vapor concentrations at this temperature were not measured.

Biphenyl pads placed over oranges in nonvented cartons stored 4 weeks at 56° F. and then held 1 week at 68° lost 84 percent of the original biphenyl and 0.4 gram remained in each. Pads placed under the fruit lost 85 percent and 0.4 gram remained. Oranges in these cartons contained 119 p.p.m. biphenyl, a value that exceeds the tolerance in the United States as well as that in West Germany (table 1). By comparison, lemons under similar conditions contained only 31 p.p.m. biphenyl (MRR-569).

Inoculated oranges in nonvented cartons, both with and without biphenyl, had decay and sporulation indexes of 100. Biphenyl reduced soilage of the noninoculated fruit from 93 percent to 37 percent (table 1).

Oranges held at this combination of temperatures, especially those in nonvented cartons, contained undesirably large amounts of biphenyl, and biphenyl did not protect them satisfactorily from spoilage.

Condition of Fruit

Effect of Biphenyl. --The effectiveness of biphenyl in reducing spoilage was greater at 40° and 48° than at 56° F., and greater in nonvented than in vented cartons.

In nonvented cartons the decay index was only half as high in cartons with biphenyl as in cartons without biphenyl. Biphenyl treatment reduced sporulation and soilage to only one-fourth of that in the untreated controls at 40° and 48° F. The biphenyl treatment was not especially effective at 56° in either vented or nonvented cartons.

Table 3 gives the average results in decay index, sporulation index, and percent soilage at each of the three basic storage temperatures. Some of the fruit included in the averages was held 1 week at 68° after storage and some was not, but all averages were obtained from lots of fruit with similar histories as to time and temperature of storage.

Table 3.--Effect of biphenyl treatment on orange spoilage

[Spoilage of oranges in cartons without biphenyl equals 100]

Carton venting and storage temperature (°F.)[1]	Decay	Sporulation	Soilage
Vented:			
40°	71	59	44
48°	72	53	44
56°	94	93	92
Nonvented:			
40°	51	26	23
48°	53	22	9
56°	91	76	36

[1] Includes after-storage holding at 68°.

Effect of carton venting. --Carton venting was beneficial when oranges were packed without biphenyl and harmful when the fruit was packed with biphenyl. Table 4 contains a summary of the results. The advantage of using nonvented cartons with biphenyl was greater at 40° and 48° than at 56° F. The greatest benefit came from the reduced soilage. Reduction in sporulation at 40° was as good as reduction of soilage at 40° but not at 48° or 56°. The decay index of inoculated oranges was almost as high in nonvented as in vented cartons.

Inoculated oranges in vented cartons with biphenyl had a decay index of 84 and a sporulation index of 79; those in similar cartons without biphenyl had a decay index of 100 and a sporulation index of 98. Forty-one percent of the noninoculated oranges in cartons with biphenyl and 43 percent of those in cartons without biphenyl were soiled.

Inoculated oranges in vented cartons with biphenyl had a decay index of 97 and a sporulation index of 96; those in similar cartons without biphenyl had decay and sporulation indexes of 100. Sixty-five percent of the noninoculated oranges in cartons with biphenyl and 87 percent of those in cartons without biphenyl were soiled (table 1). By comparison, lemons in vented cartons with biphenyl stored under these conditions had a decay index of 45, a sporulation index of 35, and 24 percent were soiled (MRR-569).

Biphenyl pads placed over oranges in nonvented cartons stored 4 weeks at 56° F. lost 68 percent of the original biphenyl and 0.8 gram remained in each. Pads placed under the fruit lost 56 percent and 1.0 gram remained. Oranges in these cartons contained 84 p.p.m. biphenyl, or somewhat more than the present tolerance in West Germany. By comparison, lemons stored under similar conditions contained only 24 p.p.m. biphenyl (MRR-569).

Inoculated oranges in nonvented cartons with biphenyl had a decay index of 93 and a sporulation index of 79; those in similar cartons without biphenyl had decay and sporulation indexes of 100. Thirty-one percent of the fruit in nonvented cartons with biphenyl and 64 percent of those in cartons without biphenyl were soiled (table 1). By comparison, lemons in nonvented cartons with biphenyl stored under these conditions had a decay index of 57, a sporulation index of 17, and 14 percent of the fruit was soiled (MRR-569).

Decay, sporulation, and soilage were high in oranges stored at this temperature regardless of biphenyl treatment or carton venting, and the biphenyl content of the oranges approached or exceeded the tolerance in West Germany.

Biphenyl pads placed over oranges in nonvented cartons stored 1 week at 56° F. and then 1 week at 68° lost 48 percent of the original biphenyl and 1.2 grams remained in each. Pads placed under the fruit lost 32 percent and 1.6 grams remained. Oranges in these cartons contained 54 p.p.m. biphenyl.

Inoculated oranges in nonvented cartons with biphenyl had a decay index of 77 and a sporulation index of 46; those in similar cartons without biphenyl had a decay index of 96 and a sporulation index of 98. Twenty percent of the noninoculated oranges in cartons with biphenyl and 87 percent of those in cartons without biphenyl were soiled (table 1).

Oranges in nonvented cartons absorbed 8 percent more biphenyl than those in vented cartons but all values were below present legal tolerances. Decay and sporulation indexes were high on fruit held at this temperature combination regardless of biphenyl and carton venting.

Four weeks at 56° F.--Biphenyl pads placed over oranges in vented cartons stored 4 weeks at 56° F. lost 84 percent of the original biphenyl and 0.4 gram remained in each. Pads placed under the fruit lost 69 percent and 0.7 gram remained. Oranges in these cartons absorbed 63 p.p.m. biphenyl. By comparison, lemons absorbed only 11 p.p.m. biphenyl under the same conditions (MRR-569).

Four weeks at 56° F. and 1 week at 68°.--Biphenyl pads placed over oranges in vented cartons stored 4 weeks at 56° F. and then held 1 week at 68° lost 98 percent of the original biphenyl and 0.1 gram remained in each. Pads placed under the fruit lost 89 percent and 0.2 gram remained. Oranges in these cartons contained 56 p.p.m. biphenyl. By comparison, lemons held under the same conditions contained 15 p.p.m. biphenyl (MRR-569).

Inoculated oranges in vented cartons both with and without biphenyl had decay and sporulation indexes of 100 and nearly all the noninoculated oranges were soiled whether biphenyl pads were used or not.

Table 4.--Effect of carton venting on orange spoilage

[Spoilage of oranges in vented cartons equals 100]

Use of biphenyl and storage temperature (°F.)[1]	Decay	Sporulation	Soilage
With biphenyl:			
40°	78	53	55
48°	79	47	26
56°	96	82	43
Without biphenyl:			
40°	110	111	104
48°	107	111	137
56°	101	100	109

[1] Includes after-storage holding at 68°.

Effect of temperature.--Oranges stored 4 weeks at a constant temperature of 40° F. were in excellent condition. Even decay of inoculated fruit was suppressed substantially, especially when 40° storage was used in conjunction with biphenyl. The oranges stored at 40° were in far better condition than those stored at 48°, both with and without biphenyl. All the oranges stored 4 weeks at 56° deteriorated excessively. Table 5 contains a summary of the effect of storage temperature on spoilage.

Biphenyl Absorbed by Oranges

Oranges absorbed more biphenyl at high than at low temperatures. The average amounts in oranges held 4 weeks at 40°, 48°, and 56° F. were in the proportion of 1.0:1.7:2.7.

Oranges held 4 weeks at 56° F. in nonvented cartons contained an average of 1.4 times as much biphenyl as those in vented cartons. Oranges absorbed from two to five times as much biphenyl as lemons (MRR-569) and twice as much as grapefruit under the same conditions. The high rate of absorption tends to reduce the concentration of biphenyl vapor in the carton and consequently reduces the effectiveness of biphenyl in controlling spoilage. The higher rate in oranges also helps account for the more rapid depletion of biphenyl from pads in orange cartons than from pads in lemon cartons.

After 4 weeks' storage at 56° F. in nonvented cartons oranges contained 84 p.p.m. biphenyl compared with 23 p.p.m. in lemons and 37 p.p.m. in grapefruit. The amounts based on surface area are 91 μg. per square centimeter in oranges, 22 in lemons, and 56 in grapefruit.

The amounts of biphenyl found in oranges after 4 weeks' storage at 56° F., 63 p.p.m. in vented cartons and 84 p.p.m. in nonvented cartons, are considerably higher than the 9-15 p.p.m. found by Rajzman (see footnote 6, p. 9) after 3 weeks at 12° C. (53.6° F.). The effect of temperature on biphenyl absorption was similar to that previously reported for lemons (MRR-569) and oranges.[7]

[7] Harvey, E. M. Absorption of Biphenyl from Biphenyl-treated Cartons by Citrus Fruits and Its Effect on Decay. U. S. Agr. Mktg. Serv. AMS-3, 16 pp. 1955.

Table 5.--Effect of storage temperature on orange spoilage: Average decay index, sporulation index, and percent soilage after 4 weeks' storage with and without biphenyl

Storage temperature (°F.) and biphenyl treatment	Decay	Sporulation	Soilage
	Index[1]	Index[1]	Percent
With biphenyl:			
40°	17	0	0
48°	52	29	7
56°	95	88	48
Without biphenyl:			
40°	38	0	0
48°	87	81	42
56°	100	100	100

[1] Decay and sporulation indexes are described on page 9.

Biphenyl Lost From Oranges During Airing

Valencia oranges lost only an average of 12 percent of the absorbed biphenyl in 1 week's airing at 68° F. in an atmosphere essentially free from biphenyl. They lost 19 percent in 2 weeks (table 6). This loss is less than one-fourth of that shown for lemons under the same conditions (MRR-569), but is larger and more uniform than the loss by oranges reported by Rajzman (footnote 6). Oranges absorbed biphenyl more rapidly and released it more slowly than lemons.

Table 6.--Biphenyl content of Valencia oranges after storing 1 week at 56° F. in nonvented cartons with biphenyl pads and loss during subsequent airing

Sample number	Biphenyl content at end of storage	Loss of biphenyl during airing at 68° F. for--	
		7 days	14 days
	P.p.m	Percent	Percent
1	25	16	20
2	24	13	21
3	30	10	23
4	25	8	12
Average	26	12	19

Biphenyl Vapor in Carton Atmosphere

The highest concentration of biphenyl vapor observed in lemon cartons was 48.7 μg. per liter of air. This concentration was found in nonvented cartons held at 68° F. The highest concentration at 50° was 11.9 μg. and at 40° 6.5 μg. These concentrations also were found in nonvented cartons. The highest concentrations found in vented lemon cartons were 24.0 μg. per liter at 68°, 10.1 μg. at 50°, and 4.8 μg. at 40°.

The concentration at 68° F. increased rapidly in both vented and nonvented cartons for 2 days. After 2 days the concentration in vented cartons decreased gradually to 2 μg. at 6 weeks. The concentration in the nonvented cartons continued to increase for a total of 2 weeks and then decreased to 11.5 μg. at 6 weeks. The concentration in nonvented cartons was at least twice that in vented cartons during most of the storage period.

The concentration at 50° F. peaked in 1 week in the vented cartons and in 1 and 3 weeks in nonvented cartons. Nonvented cartons had substantially higher concentrations than vented cartons until near the end of the 7-week storage.

The concentration at 40° F. rose gradually to a low peak at 3 weeks and then fell slowly. The concentration when storage was discontinued after 9 weeks was at least one-half of the maximum. Details of biphenyl vapor concentrations in lemon cartons appear in figure 3.

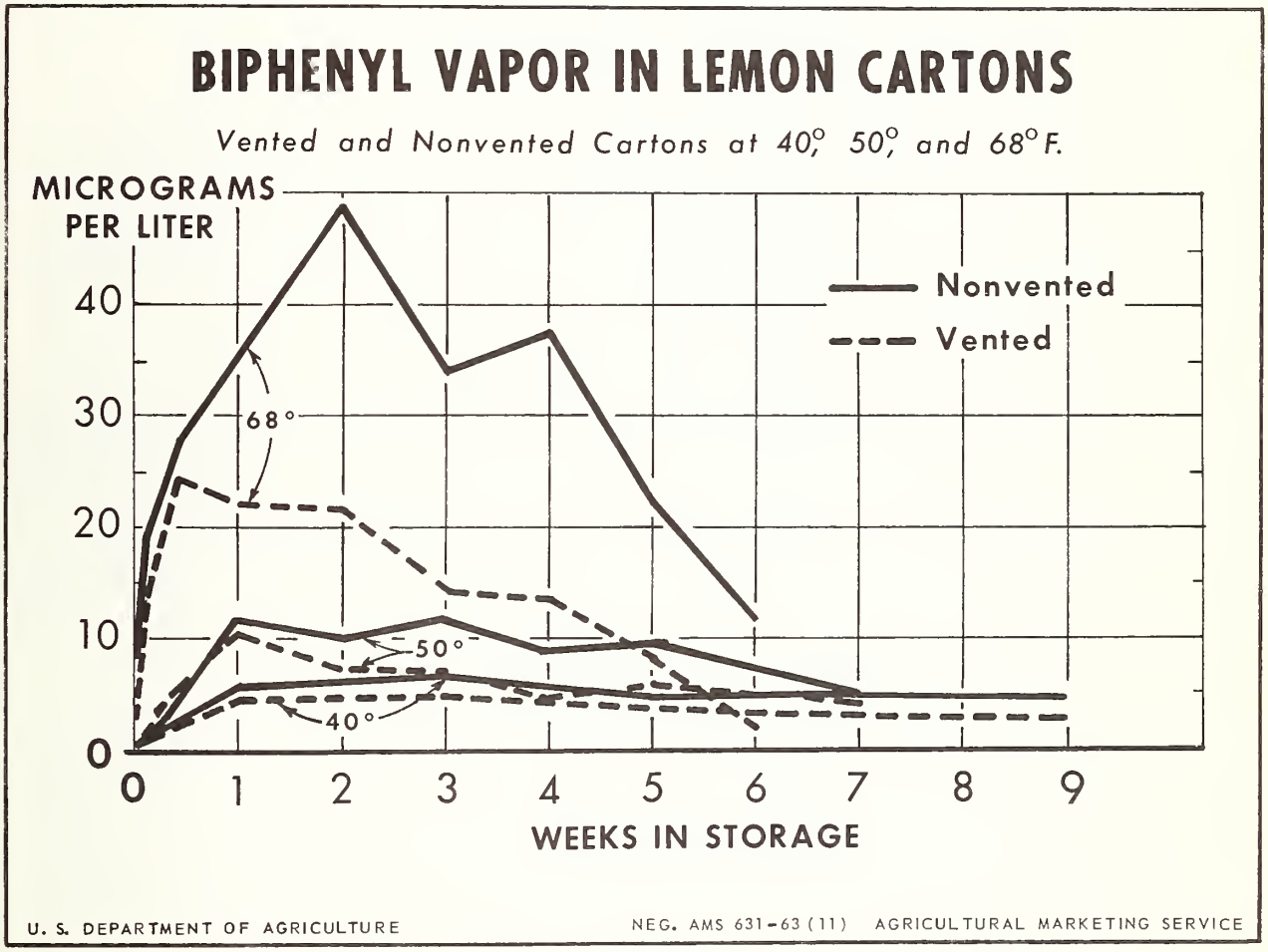

FIGURE 3

Effect on Spoilage of Renewing Biphenyl Pads

Renewing the biphenyl pads in lemon cartons when they were transferred from 40° F. storage to 68° failed to improve the condition of the fruit at the end of the holding period. Table 7 shows that the deterioration may even have been aggravated by the extra handling involved in replacing the biphenyl pads.

Table 7.--Effect on spoilage of renewing biphenyl pads during storage of lemons in cartons. Lemons were stored 4 weeks at 40° F., then 1 week at 68°. Pads were renewed at transfer from 40° to 68°

Pad renewal	Decay[1]	Sporulation[1]	Soilage	Biphenyl content	
				Pads	Fruit
	Index	Index	Percent	Percent	P.p.m.
Pads not renewed	84	2	6	1.5	32
Pads renewed	89	5	9	1.9	35

[1] Decay and sporulation indexes are described on page 9.

Biphenyl in Lemons Stored in Tight Containers

Lemons in cartons packed in tight containers absorbed 2 to 3 times as much biphenyl as those stored in nonvented cartons. Lemons stored at 56° F. 3 weeks in gasketed steel drums and then held 3 days at the same temperature outside the drums contained 70 p.p.m. biphenyl. Other lemons stored in tight wooden containers with gasketed lid at the same time and temperature contained 51 p.p.m. biphenyl. The lower biphenyl content of the lemons in the wooden containers reflects the difference in tightness of the two kinds of containers.

These figures are indicative of the amount of biphenyl lemons would absorb during overseas transit in tight shipping containers. The wooden container more nearly resembles the ship container than the steel drum. The biphenyl absorbed by these lemons is high compared with 24 p.p.m. absorbed by lemons held 4 weeks at 56° F. in nonvented cartons without tight outer containers (MRR-569). The tolerance of 70 p.p.m. allowed by West Germany should not be exceeded during a 4-week transit period. The lower transit temperature usually used on shipboard should give additional assurance that the amount of biphenyl absorbed will be within the permissible level. Additional tests will be needed to establish the best acceptable transit conditions.

Grapefruit

Loss of Biphenyl from Pads

Biphenyl pads in vented cartons stored 4 weeks at 56° F. lost 1.6 times as much biphenyl as those in nonvented cartons. Biphenyl pads placed over the fruit in grapefruit cartons stored 4 weeks at 56° F. lost 1.3 times as much biphenyl as those placed under the fruit. Biphenyl usually escaped faster from pads in grapefruit cartons than from pads in lemon cartons, and at about the same rate as from pads in orange cartons.

Results with Stored Fruit

One week at 56° F. and one week at 68°. --Grapefruit was stored only at 56° F.; it is sensitive to chilling injury in the 40's and lower.

Biphenyl pads placed over grapefruit in vented cartons stored 1 week at 56° F. and then held 1 week at 68° lost 81 percent of the original biphenyl and only 0.4 gram remained in each. Pads placed under the fruit lost 68 percent and 0.8 gram remained. Grapefruit in these cartons contained 21 p.p.m. biphenyl. Biphenyl vapor concentration in grapefruit cartons was not measured.

Inoculated grapefruit in vented cartons with biphenyl had a decay index of 70 and a sporulation index of 76; those in similar cartons without biphenyl had a decay index of 93 and a sporulation index of 67. Sixty-two percent of the noninoculated grapefruit in cartons with biphenyl and 87 percent of those in cartons without biphenyl were soiled.

Biphenyl pads placed over grapefruit in nonvented cartons stored 1 week at 56° F. and then held 1 week at 68° lost 50 percent of the original biphenyl and 1.2 grams remained in each. Pads placed under the fruit lost 41 percent and 1.4 grams remained. Grapefruit in these cartons contained 37 p.p.m. biphenyl.

Inoculated grapefruit in nonvented cartons with biphenyl had a decay index of 56 and a sporulation index of 37; those in similar cartons without biphenyl had a decay index of 100 and a sporulation index of 57. Twenty-four percent of the noninoculated fruit in cartons with biphenyl and 93 percent of the fruit in cartons without biphenyl were soiled (table 8).

Four weeks at 56° F. --Biphenyl pads placed over grapefruit in vented cartons stored 4 weeks at 56° F. lost 84 percent of the original biphenyl and 0.4 gram remained in each. Pads placed under the fruit lost 68 percent and 0.8 gram remained. Fruit in these cartons contained 26 p.p.m. biphenyl.

Inoculated grapefruit in vented cartons with biphenyl had a decay index of 82 and a sporulation index of 81; fruit in similar cartons without biphenyl had decay and sporulation indexes of 100. Sixty-five percent of the noninoculated fruit in vented cartons with biphenyl and 100 percent of the fruit in cartons without biphenyl were soiled.

Biphenyl pads placed over grapefruit in nonvented cartons stored 4 weeks at 56° F. lost 52 percent of the original biphenyl and 1.1 grams remained in each. Pads placed under the fruit lost 39 percent and 1.4 grams remained. Fruit in these cartons contained 37 p.p.m. biphenyl compared with 84 p.p.m. in oranges and 23 p.p.m. in lemons (MRR-569) held under the same conditions.

Inoculated fruit in nonvented cartons with biphenyl had a decay index of 49 and a sporulation index of 40; fruit in similar cartons without biphenyl had decay and sporulation indexes of 100. Thirty-two percent of the noninoculated fruit in cartons with biphenyl and 100 percent of the fruit in cartons without biphenyl were soiled (table 8).

Biphenyl pads in nonvented cartons lost only 0.6 as much biphenyl as those in vented cartons under the same conditions. Grapefruit in nonvented cartons absorbed 1.8 times as much biphenyl as fruit in vented cartons, but the biphenyl content of all the fruit was below all present legal tolerances. The decay index of fruit in vented cartons with biphenyl was 1.7 times as high as that of fruit in nonvented cartons, the sporulation index was twice as high, and the percent soilage twice as high.

Decay, sporulation, and soilage were less than half as severe in nonvented cartons with biphenyl as in those without biphenyl. Biphenyl was less effective in vented than in nonvented cartons.

Table 8.--Deterioration of grapefruit stored with and without biphenyl in vented and nonvented cartons[1]

Temperature (° F.), length of storage, and carton venting	Biphenyl content			Decay of inoculated fruit[2]		Sporulation of inoculated fruit[2]		Soilage of noninoculated fruit[2]	
	Pads[3]		Fruit	With biphenyl	Without biphenyl	With biphenyl	Without biphenyl	With biphenyl	Without biphenyl
	Top	Bottom							
56°:	Grams	Grams	P.p.m.	Index	Index	Index	Index	Percent	Percent
1 week plus 1 week at 68°									
Vented	0.4	0.8	21	70	93	76	67	62	87
Nonvented	1.2	1.4	37	56	100	37	57	24	93
4 weeks									
Vented	.4	.8	26	82	100	81	100	65	100
Nonvented	1.1	1.4	37	49	100	40	100	32	100
4 weeks plus 1 week at 68°									
Vented	(4)	(4)	(4)	100	100	100	100	100	100
Nonvented	(4)	(4)	(4)	100	100	100	100	100	100

[1] Each value with biphenyl is the average of 3 cartons; without biphenyl 1 carton. Each carton contained 15 inoculated and 33 noninoculated fruits. [2] Decay and sporulation indexes are described on page 9. [3] Average initial value 2.4 grams per pad. [4] Bad soilage made suitable analytical samples unavailable.

All these forms of spoilage were more severe on grapefruit than on lemons held under the same conditions, both with and without biphenyl (compare with MRR-569).

Four weeks at 56° F. and 1 week at 68°. --Biphenyl in pads and fruit after storing 4 weeks at 56° F. and holding 1 week at 68° could not be measured because the decay was so extensive that no suitable material was available for sampling.

Decay and sporulation indexes of the inoculated fruit and the percent soilage of the noninoculated fruit reached 100 in all cartons regardless of carton venting and the use of biphenyl (table 8). Grapefruit deteriorated more at these temperatures than lemons held under the same conditions (compare with MRR-569).

Mandarins

Results with Stored Fruit

One week at 38° F. --A biphenyl pad placed over mandarins in a vented carton and stored at 38° F. lost 17 percent of the original biphenyl (1.8 grams per pad) and 1.5 grams remained. The pad placed under the fruit lost 6 percent and 1.7 grams remained. Air near the center of the carton contained 5 μg. biphenyl vapor per liter and mandarins in this carton contained 14 p.p.m. biphenyl after 1 week's storage.

Mandarins absorbed biphenyl more rapidly than lemons, which contained 5.2 p.p.m. after 1 week at 40° F. (MRR-569), and perhaps slightly more rapidly than oranges, which contained 22 p.p.m. after 4 weeks at 40°. Available data do not permit a direct comparison with other fruit stored at the same temperature for the same length of time.

None of the fruit in this carton was inoculated and no decay developed in storage.

One week at 38° F. and 1 day at 68°. --Mandarins stored in vented cartons 1 week at 38° F. and then held 1 day at 68° contained 20 p.p.m. biphenyl in a sample taken at random. Mandarins in another carton sampled by layers contained 16 p.p.m. in the top layer, 21 p.p.m. in the middle layer, and 28 p.p.m. in the bottom layer. Pads and atmosphere in these cartons were not analyzed.

Biphenyl Lost from Mandarins During Airing

Mandarins spread on open trays lost 25 percent of the absorbed biphenyl in 2 days at 68° F. The biphenyl content decreased from 20 p.p.m. to 15 p.p.m. The rate of loss is much higher than the highest rate found in oranges and equals the highest rate found in lemons (MRR-569).

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