Effect of Biphenyl Treatment and Carton Ventilation on Decay and Soilage of California Lemons In Overseas Shipments

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SUMMARY

Three test shipments of lemons were made from Los Angeles, Calif., to Hamburg, West Germany. Three static tests with fruit from the same lots used in the test shipments were held at Riverside in a stationary model car. This car is similar to a standard ice-refrigerated railroad car, but has only about one-sixth of its capacity.

Rate of cooling was most rapid in the third overseas shipment and slowest in the second. The high decay and soilage found in the second test and the low amounts in the third were related to transit temperatures, but original fruit condition and long transit time of the second test undoubtedly contributed to these differences.

Lemons in cartons next to dunnage cooled more rapidly than those in cartons away from dunnage. Lemons in vented cartons cooled more rapidly and were maintained at a slightly lower temperature in transit than those in nonvented cartons.

When biphenyl was used, overseas shipments of fruit in nonvented cartons had slightly higher amounts of decay and soilage on arrival and lower amounts at the end of the 2-week holding period than did fruit in vented cartons. Additional testing is necessary to determine conclusively whether venting aids in the delivery of good lemons to the overseas consumer.

Lemons in vented cartons softened more from loss of moisture than those in nonvented cartons, but their color was not affected noticeably.

Biphenyl reduced soilage (dusting of sound fruit with spores from decaying fruit within the carton) materially and usually significantly in fruit in both vented and nonvented cartons in both the overseas shipments and in the static tests.

Decay caused by organisms other than Penicillium was slightly lower in fruit packed in vented cartons than in that packed in nonvented cartons, and slightly lower in lemons packed in cartons treated with biphenyl than in those without this treatment; but these small differences were not statistically significant.

More decay and soilage usually developed in the smaller than in the larger of the two sizes used, but the results are not conclusive.

INTRODUCTION

The use of biphenyl in vapor form is generally considered effective in reducing decay in citrus fruits during marketing. In spite of the use of biphenyl, reports of excessive decay in fruit exported to European markets have been received frequently. This led representatives of the American citrus industry and related industries to request the Agricultural Marketing Service and the California Citrus Experiment Station to investigate ways of improving the effectiveness of biphenyl in reducing decay and soilage.

For this purpose three test shipments of lemons were made from Los Angeles to Hamburg via the Panama Canal during the summer of 1959. Three corresponding static

tests were made with fruit from the same lots at the citrus experiment station at Riverside, Calif., using stationary model refrigerated cars. A fourth static test was made on oranges as well as lemons.

These tests were made to obtain additional data on (1) the usefulness of biphenyl in reducing decay of citrus fruit during transit, and for 2 weeks after unloading, a period long enough to provide for distribution through the usual market channels; (2) the desirability of ventilating holes in the fiberboard containers, and (3) biphenyl accumulation in the fruit as influenced by carton ventilation, transit and storage time, and temperature.

This study is part of a broad program of research aimed at expanding the market for agricultural products.

MATERIALS AND METHODS

The first and third overseas test shipments consisted of 192 cartons of lemons and the second of 128 cartons. In each shipment lemons were divided into groups of 64 cartons and each group was stowed in a different part of the ship's hold. One-half of the cartons were vented with eighteen 1-inch holes, three in each of two sides, six in the top, and six in the bottom. The remaining cartons were not vented. One-half of the vented cartons and one-half of the nonvented ones were treated with biphenyl. The other cartons served as controls.

Two sizes of lemons were used: 150 per carton and 180 per carton. Each subsample within a shipment was made up of equal numbers of cartons of each size. Efforts were made to obtain good uniformity of test fruit within a shipment. As far as possible, the two sizes were taken from the same packinghouse lots; consequently, they were picked from the same grove at the same time. Large differences in proportion of fruit in the two size classes prevented complete uniformity in the two sizes of test fruit.

The lemons were dipped in a warm solution of soda ash and sprayed with 2,4-D and water wax before storage for curing. These are common commercial practices. The biphenyl treatment consisted of placing a sheet of biphenyl-impregnated paper under the fruit and another on top of the fruit immediately under the carton lid when the fruit was packed for shipment. As each sheet contained 2.35 grams of biphenyl according to manufacturer's specifications, each carton was supposedly supplied with 4.70 grams. The cartons were constructed of corrugated fiberboard with the lid telescoping over the lower portion, giving two or more thicknesses of fiberboard on all sides.

In the statistical evaluation, percentage of decay and percentage of soilage were transformed to angles by multiplying the arc sine by the square root of the percentage.

In all ship tests, the cartons were stowed so that all treatments had comparable transit conditions with respect to air movement, with a minimum of transfer of biphenyl vapor from treated to nontreated areas.

The schedules and harbor storage temperatures of the three test shipments at destination were as follows:

	Shipment number		
	1	2	3
Fruit packed	June 11	June 30	July 17
Fruit loaded on ship	June 14-15	July 2-3	July 18-19
Ship departed	June 16	July 3	July 21
Ship unloaded	July 10	Aug. 17	Aug. 17
Arrival inspection	July 11	Aug. 18	Aug. 19
Second inspection	July 27-29	Aug. 27-28	Aug. 31-Sept. 2
Storage temperature at harbor			
Range, °F.	63-72	60-75	60-75
Average	69	67	67

The second overseas test shipment required the unusually long period of 45 days to reach the Hamburg harbor. The principal reason for the delay was an 11-day stay at Havana, where the ship put in to take on a cargo of sugar. A political celebration was in progress at that time, and the movement of goods was nearly at a standstill.

Each shipment had 16 thermographs which recorded transit temperatures in the centers of nontest cartons located next to those containing test fruit. Eight thermographs were placed in two locations used for test fruit in each of the shipments. In each location four of the thermographs were in vented cartons and four in nonvented. Thermographs were placed in vented and nonvented cartons stowed next to dunnage and in similar cartons stowed one carton-width away from dunnage in the first and third shipments. All cartons in the second shipment were exposed to an air channel on one side (top or bottom). As the thermograph clocks and charts are made to operate 30 days, no temperature records were obtained for the latter part of the second test shipment, which was en route 45 days.

The first and third shipments had vertical dunnage consisting of 1- by 2-inch boards every third stack so that air channels would correspond with the direction of air movement. The second shipment was stowed with horizontal dunnage at every second layer. The air movement in this ship was athwartship (crosswise) with direction of movement reversed periodically.

One-fourth of the cartons of fruit from each shipment was examined immediately after unloading at Hamburg (arrival inspection). The remainder were examined after storage at the harbor without refrigeration for about 2 weeks (second inspection). Storage time and temperature are given on page 2.

Model refrigerator cars used for the static tests are similar to standard ice-refrigerated railroad cars equipped with electrically driven bunker fans. In these tests the model cars were filled to capacity with 144 standard citrus cartons stowed in a chimney pattern. The two bunkers had combined capacity of 3.6 tons of ice and were filled to capacity at the start of the test and refilled every 5 days. The fans delivered a total of 2,500 c.f.m.; they operated constantly until the temperature reached about 40° F., and then they alternated on and off for periods of 6 hours each. Temperatures were obtained with a recording potentiometer connected to thermocouples inserted into fruit in cartons distributed throughout the load. The model cars were not agitated.

RESULTS

Rate of Cooling Aboard Ship

The average temperatures recorded by thermographs placed in the center of fruit cartons when the ships were loaded were:

Test shipment	1	2	3
Range, ° F.	65-74	65-70	70-74
Average	68.0	67.5	72.1

The average recorded temperatures were lowered about 16 degrees in the first shipment, 10 degrees in the second, and 20 degrees in the third during the first 4 days of cooling in the ships' holds. The average temperature was lowered to 55 ° F. in about 3.5 days in the first shipment, in 5.3 days in the second, and in 3.1 days in the third. During the period of rapid cooling, the average cooling rate was 3.7 degrees per day in the first shipment, 2.3 degrees in the second, and 5.7 degrees in the third.

Cooling in relation to dunnage. The average of all recorded temperatures in cartons adjacent to dunnage in the first and third shipments was lowered to 55° F. in 2.8 days, whereas similar cartons one carton-width away from dunnage required 3.7 days

for a similar temperature drop. The average cooling rate during this period was 5.1 degrees per day in the cartons next to dunnage and 3.8 degrees per day in cartons one carton-width away from the air channels provided by dunnage. In the second shipment, one surface of each carton was exposed to an air channel.

Cooling in relation to carton venting. The average of all recorded temperatures in nonvented cartons in the three shipments was lowered to 55° F. in 4.7 days, whereas a similar temperature reduction in vented cartons was accomplished in 3.0 days. This is equivalent to 3.0 degrees cooling a day in nonvented cartons and 4.7 degrees in vented ones. The average temperatures in nonvented and vented cartons in each of the three shipments during transit periods up to 30 days were:

Shipment No.	Vented cartons °F.	Nonvented cartons °F.
1	49.5	52.3
2	50.8	53.2
3	49.1	50.1

Average temperatures in vented and nonvented cartons in each test are shown in figure 1.

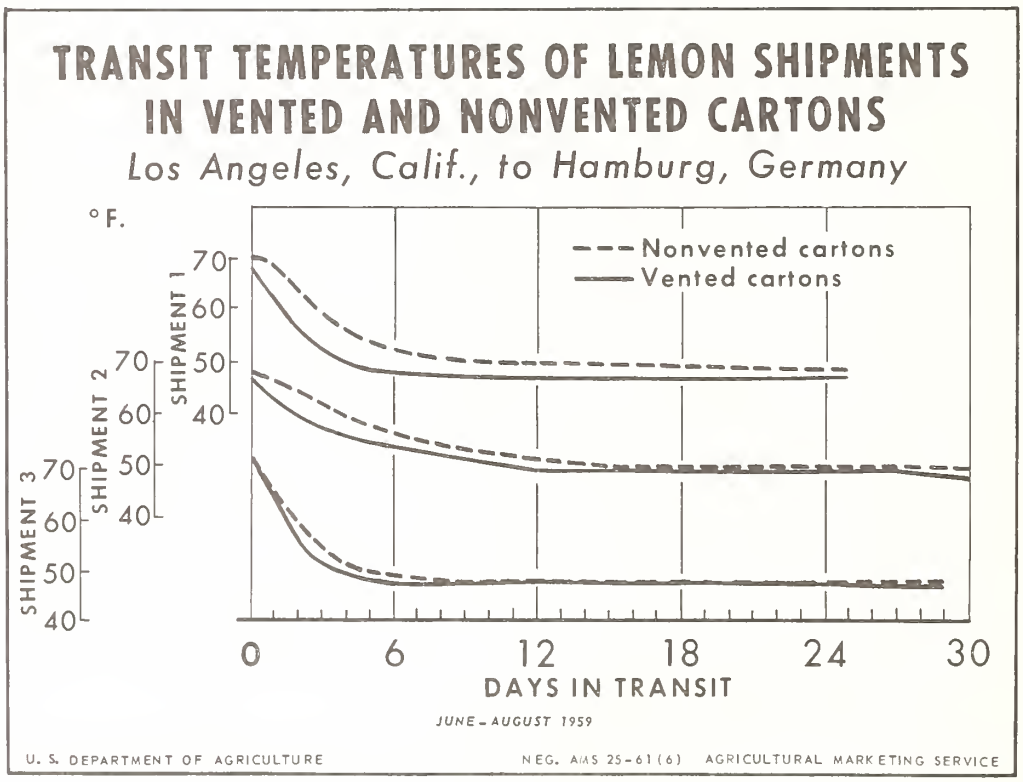

Figure 1

Combined effect of dunnage and carton venting on rate of cooling. The nearness to dunnage influenced the rate of temperature reduction in nonvented cartons more than in vented ones. For example, in the first shipment the temperature was reduced at an average rate of 4.2 degrees F. per day in nonvented cartons adjacent to dunnage and only 2.4 degrees per day in similar cartons placed one carton-width away from dunnage. The corresponding rates in vented cartons were 5.2 for those adjacent to dunnage and 5.0 degrees for those one carton-width away. These average rates prevailed from the start of cooling until the average temperature in each location reached 55°.

Rate of Cooling in Static Test No. 1

The temperature of the lemons in static test 1 ranged from 59° to 62° F. at the time of loading. Fruit in vented cartons reached 40° in 44 hours, whereas 59 hours was required in nonvented cartons. Subsequent "transit" temperature was 39°. A higher constant transit temperature could not readily be maintained in the model refrigerator cars because they were refrigerated with ice, and no thermostatic control was available. The temperatures in the subsequent static tests were similar to those in test No. 1.

Carton Venting in Relation to Decay and Soilage

Detailed data on decay and soilage (dusting of sound fruit with spores from decaying fruit within the carton) of lemons in the ship tests are given in table 1 and in the static tests in table 2. A summary averaging the results in all ship tests is given in figure 2. An average of 5.4 percent of the fruit shipped to Hamburg in nonvented cartons without biphenyl was decayed on arrival compared with 3.2 percent in vented cartons. At the second inspection these values were 14.7 percent in nonvented cartons and 7.6 percent in vented ones. In the static tests the average decay after the simulated transit period and 7 to 19 days in the laboratory was 9.2 percent in nonvented cartons without biphenyl and 7.8 percent in vented ones. The relatively low decay in nonvented cartons without biphenyl in the static tests may be attributed to more rapid cooling and lower transit temperature than in the ships. A short holding period for two of the tests also helped to lower decay.

Venting of cartons containing biphenyl usually resulted in a small statistically nonsignificant reduction in lemon decay at the arrival inspection in the ship tests when compared with nonvented cartons containing biphenyl. At the second inspection, less decay was found in lemons in nonvented cartons than in vented ones in all three tests, averaging 4.2 percent for nonvented cartons and 4.9 percent for vented, but these values were not statistically different. Similarly, in the static tests the averages of 3.3 percent decay in nonvented cartons and 4.8 percent in vented ones were not statistically different.

The outstanding effect of carton venting was to reduce the amount of soilage at the arrival inspection in the ship tests in packages without biphenyl. The percentage of soiled lemons in nonvented cartons without biphenyl was about five times as high as in vented ones without biphenyl, or 41.8 percent compared with 7.7 percent. The difference at the end of the 2-week holding period, 43.5 percent compared with 17.3 percent, was less pronounced but still highly significant. Lemon soilage in similar packages in the static tests at the end of the combined refrigerated storage and laboratory holding period averaged 26.3 percent in nonvented cartons and 19.3 percent in vented ones. The difference was statistically significant.

The effect of carton venting on soilage was smaller in the biphenyl-treated than in the control lots. When the lemons arrived, 1.7 percent of those in nonvented cartons containing biphenyl and 1.0 percent of those in similar vented cartons were soiled. The difference was not statistically significant. After the holding period the differences were reversed in both the ship tests and the static tests (no data on "arrival" soilage were obtained in the static tests). Differences in soilage after holding were statistically significant in the first and second ship tests and in the second and third static tests. The nonvented biphenyl-treated cartons in the ship tests contained an average of 3.3 percent soiled fruit, whereas 6.2 percent of the fruit in similar vented cartons was soiled. Similarly, an average of 1.6 percent of the fruit in nonvented biphenyl-treated cartons in the static tests was soiled and 5.5 percent of the fruit in vented cartons.

The lower decay and soilage observed in lemons in vented cartons upon arrival of ship tests at Hamburg can be attributed to the more rapid cooling and the slightly lower transit temperatures of fruit in vented cartons than in nonvented ones. However, the venting that permitted more rapid cooling during transit also permitted more rapid dissipation of biphenyl vapor during transit and during storage after the packages were

TABLE 1.--Decay and soilage in California lemons in shipping tests to Hamburg, West Germany, 1959

Shipment, treatment, and carton venting	On arrival				Second inspection			
	Penicillium	Other decay	Total decay	Soilage	Penicillium	Other decay	Total decay	Soilage
Shipment 1: departed June 16, unloaded July 10[1]								
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Without biphenyl								
Vented cartons.....	2.3	0.6	2.9	9.1	4.1	1.7	5.8	16.6
Nonvented cartons..	3.4	.5	3.9	52.8	9.4	1.1	10.5	47.3
With biphenyl								
Vented cartons.....	1.0	.6	1.6	1.0	2.4	1.3	3.7	8.0
Nonvented cartons..	1.9	.7	2.6	1.7	2.3	1.0	3.3	2.1
Shipment 2: departed July 3, unloaded Aug. 17[2]								
Without biphenyl								
Vented cartons.....	2.6	1.5	4.1	10.8	8.9	4.2	13.1	27.8
Nonvented cartons..	6.9	1.4	8.3	50.6	19.4	5.3	24.7	56.0
With biphenyl								
Vented cartons.....	2.8	.8	3.6	1.5	4.8	3.3	8.1	7.1
Nonvented cartons..	3.1	1.5	4.6	2.2	3.3	3.5	6.8	4.2
Shipment 3: departed July 21, unloaded Aug. 17[1]								
Without biphenyl								
Vented cartons.....	2.5	.1	2.6	3.1	2.0	2.0	4.0	7.5
Nonvented cartons..	3.7	.2	3.9	22.1	5.9	3.1	9.0	27.2
With biphenyl								
Vented cartons.....	1.3	.1	1.4	.4	1.8	1.0	2.8	3.7
Nonvented cartons..	.7	.3	1.0	1.1	1.3	1.3	2.6	3.7
Average of 3 shipments								
Without biphenyl								
Vented cartons.....	2.4	.8	3.2	7.7	5.0	2.6	7.6	17.3
Nonvented cartons..	4.7	.7	5.4	41.8	11.5	3.2	14.7	43.5
With biphenyl								
Vented cartons.....	1.7	.5	2.2	1.0	3.0	1.9	4.9	6.2
Nonvented cartons..	1.8	.9	2.7	1.7	2.3	1.9	4.2	3.3

[1] Each figure is average of percentage of decay or soilage in 12 cartons of fruit for "on arrival" inspection and 36 cartons for second inspection.

[2] Each figure is average of percentage of decay or soilage in 8 cartons of fruit for "on arrival" inspection and 24 cartons for second inspection.

TABLE 2.--Decay and soilage in California lemons during static tests followed by holding in a laboratory at Riverside, June through August, 1959

Test, treatment, and carton venting	Total decay	Soilage
Test 1: loaded June 12, unloaded July 13, inspected July 20[1]		
Without biphenyl	*Percent*	*Percent*
Vented cartons	9.8	---
Nonvented cartons	9.9	---
With biphenyl		
Vented cartons	6.7	---
Nonvented cartons	3.1	---
Test 2: loaded July 6, unloaded July 20, inspected July 27[1]		
Without biphenyl		
Vented cartons	8.8	25.2
Nonvented cartons	10.8	32.6
With biphenyl		
Vented cartons	4.6	4.9
Nonvented cartons	3.3	.8
Test 3: loaded July 16, unloaded Aug. 10, inspected Aug. 29[1]		
Without biphenyl		
Vented cartons	4.7	13.5
Nonvented cartons	9.7	19.9
With biphenyl		
Vented cartons	3.2	6.1
Nonvented cartons	3.5	2.5
Average of 3 tests:		
Without biphenyl		
Vented cartons	7.8	19.3
Nonvented cartons	9.2	26.3
With biphenyl		
Vented cartons	4.8	5.5
Nonvented cartons	3.3	1.6

[1] Each figure is average of percentage of decay or soilage in 36 cartons of fruit.

removed from refrigeration. The temperature during the storage period especially favored decay development and also an increased rate of biphenyl sublimation, with a resultant decrease in biphenyl remaining in the sheets for future protection. Loss of biphenyl to the outside air may be reflected in increased decay and soilage, as the supply in the cartons is limited. Biphenyl measurements made in the fourth static test, and which are discussed in the section on the fate of biphenyl in cartons support this relationship between biphenyl and decay and soilage.

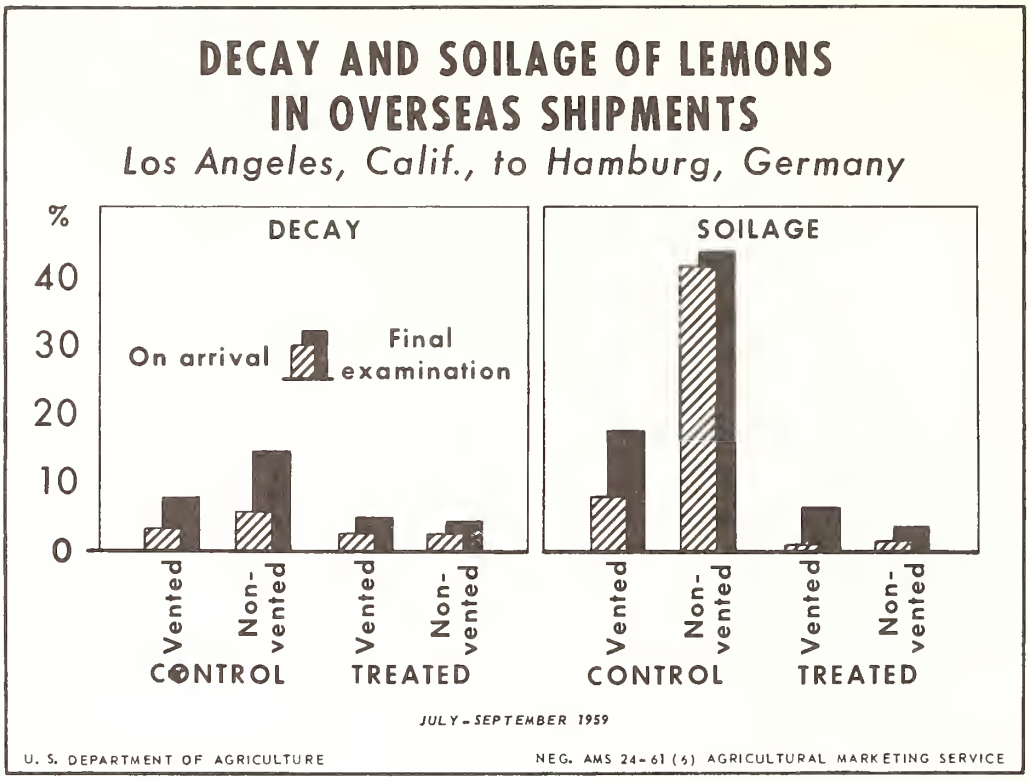

Figure 2

Carton Venting in Relation to Fruit Condition

Fruit in vented cartons was usually softer than that in nonvented cartons at the second inspection. Eighty percent of the fruit classified as moderately soft at the second inspection of the third test was in vented cartons, whereas 75 percent of the fruit classified as moderately firm was in nonvented cartons. Other fruit fell between these two groups in degree of softness. Fruit of the first and second test shipments were not classified in this manner, but the same difference in firmness prevailed.

No relation between fruit color and carton venting could be detected in either test fruit or commercial shipments.

Biphenyl Treatment in Relation to Decay and Soilage

Biphenyl reduced decay and soilage, usually significantly, in both vented and nonvented cartons in all ship and static tests (see tables 1 and 2 and figure 2). The greatest decrease in decay was found in fruit packed in nonvented cartons where the average decay was reduced from 14.7 percent to 4.2 percent in the ship tests after the 2-week holding period at the harbor, and from 9.2 percent to 3.3 percent in the static tests after the holding period in the laboratory. Biphenyl reduced the average decay to about one-third of the values in the control lots in both kinds of tests.

Biphenyl reduced decay in lemons packed in vented cartons from an average of 7.6 percent in the controls to 4.9 percent in the treated packages in the ship tests after the 2-week holding period at the harbor, and from 7.8 percent to 4.8 percent in the static tests after the holding period in the laboratory. Biphenyl reduced decay to about two-thirds of the control values in each test.

Biphenyl was more effective in reducing soilage than in reducing decay. This feature of biphenyl is attractive to lemon shippers, as soiled fruit brings lower returns on the markets than similar clean fruit. In nonvented cartons in the ship tests, average lemon soilage was reduced from 43.5 percent in the control cartons to 3.3 percent in cartons containing biphenyl at the end of the 2-week holding period. In the static tests with nonvented cartons, biphenyl reduced the average soilage from 26.3 percent in the control cartons to 1.6 percent in cartons containing biphenyl at the end of the holding period. Soilage in lemons packed in vented cartons and examined at the end of the holding period averaged 17.3 percent in the controls and 6.2 percent in cartons treated with biphenyl in the ship tests, and 19.3 and 5.5 percent in the static tests. Biphenyl reduced soilage about equally in the ship and static tests in both nonvented and vented cartons.

Biphenyl reduced the average ratio of soiled fruits to decayed fruit from 3.2 to 0.8 in all inspections of overseas test shipments, and from 2.5 to 0.8 in fruit in static tests.

Fruit Size in Relation to Decay and Soilage

Efforts were made to obtain fruit of uniform history in the two sizes (150 and 180 fruits per carton), but more decay and soilage usually developed in the smaller fruit than in the larger (table 3). This relationship was usually maintained whether or not biphenyl was used. Exceptions were noted in the soilage of lemons in nonvented cartons without biphenyl at both inspections in the first and third test but not in the second. These three tests did not provide sufficient data to permit definite conclusions to be drawn regarding the relation between fruit size and storage life.

TABLE 3.--Percent of decay and soilage in lemons as related to size, type of carton, and treatment with biphenyl in overseas tests

Time of inspection, treatment, and carton venting	Decay		Soilage	
	180 per carton	150 per carton	180 per carton	150 per carton
Arrival inspection:				
Without biphenyl:	*Percent*	*Percent*	*Percent*	*Percent*
Vented	4.0	2.2	9.0	6.1
Nonvented	5.5	5.3	37.9	47.0
With biphenyl:				
Vented	2.4	2.0	1.2	.7
Nonvented	3.1	2.3	1.9	1.4
Second inspection:				
Without biphenyl:				
Vented	8.9	5.2	19.9	14.2
Nonvented	16.4	12.7	43.2	44.0
With biphenyl:				
Vented	5.8	3.7	6.9	5.4
Nonvented	4.9	3.5	4.4	2.0

Fate of Biphenyl in Cartons

Quantitative data were sought on the amount of biphenyl absorbed by the fruit because of legal restrictions on permissible amounts, and on the amount remaining in the application sheets. The amount of biphenyl left on the sheets influences to a large extent the concentration in the carton atmosphere and therefore the amount of decay control that can be expected. Published reports of experimental work on the reduction of decay and soilage of citrus fruits through the use of biphenyl usually state or imply that only the vapor phase is effective (3, 6, 7, 8). Grierson (4), however, noted a moderate amount of residual inhibiting effect after the biphenyl source was removed from the packages. (Underscored figures refer to Literature Cited, p. 14.)

Samples of 40 lemons per carton were transferred to perforated polyethylene bags at the second inspection of test 1 at Hamburg, and analyzed for biphenyl by a commercial laboratory. Ten or more samples of each treatment were prepared. Table 4 gives data on biphenyl content of lemons for the first overseas test and the fourth static test.

The disparity in temperature between the ship test and the static test precludes satisfactory comparison. However, less biphenyl accumulated in lemons packed in vented than in nonvented cartons in both tests. The results of the static test suggest that little biphenyl enters the fruit during a 1-month transit period when the temperature is close to 40° F.

Commercial shipments from the United States procured from receivers at Hamburg contained an average of 9 (range 0.3 to 28) p.p.m. (parts per million). All values, both experimental and commercial, obtained in the analysis of lemons originating in the United States were well within the tolerance of 70 p.p.m. currently in effect in West Germany.

Samples of biphenyl sheets and of lemons from representative cartons in the fourth static test were analyzed for biphenyl content after the simulated transit period and again after the holding period in the laboratory. The results have been calculated on a per-carton basis and are given in table 5. The initial application was assumed to be 2.35 grams per sheet or 4.70 grams per carton. This is the amount specified for the sheets by the manufacturer and a few analyses of fresh sheets were in reasonably close agreement with this value. The loss to the air and to the carton walls was calculated as the difference between the amount assumed to be present initially and the combined amounts found in the fruit and in the biphenyl sheets at the end of the test. More biphenyl remained in the sheets in nonvented cartons than in vented ones, both "on arrival" (first inspection) and at the end of the laboratory holding period (second inspection). The residue in the fruit was alike in the two kinds of cartons "on arrival" but was somewhat higher in fruit in nonvented cartons at the end of the holding periods, indicating definitely higher concentration in the atmosphere of the nonvented cartons during the storage period. The loss to the air and the carton walls was somewhat higher in vented cartons than in nonvented ones at both inspections.

The high soilage (9.7 percent) of lemons in the vented cartons suggests that the biphenyl concentration in the atmosphere of these cartons had become so low prior to the end of the laboratory holding period that little or no decay or sporulation control remained. The small amount of soilage (1.2 percent) in lemons in the nonvented cartons suggests that the biphenyl vapor level was still high enough to be fairly effective in controlling sporulation.

Little is known about the biphenyl concentration needed to give acceptable control of sporulation by Penicillium growing on fruit. Farkas and Aman (3) demonstrated that in cultures growing on nutrient agar in petri dishes, both of the common species of Penicillium, when held at 25° C., failed to grow in air saturated with biphenyl vapor (80 micrograms biphenyl per liter of air). Calculations based on data published by Bradley and Cleasby (1) indicate that 87.3 micrograms per liter corresponds to saturation at 25° C., or practically the same as given by Farkas and Aman.

TABLE 4.--Average biphenyl content of lemons in vented and nonvented cartons

Test	Vented cartons			Nonvented cartons		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Shipping test No. 1:						
Inspected after holding 2 weeks in unrefrigerated storage in Hamburg[1].....	*P.p.m.* 3	*P.p.m.* 16	*P.p.m.* 9	*P.p.m.* 15	*P.p.m.* 30	*P.p.m.* 22
Static test No. 4:						
Inspected after 4 weeks in model car.....	1	3	2	---	---	3
Inspected after 2 weeks in laboratory at Riverside..	20	29	24	26	46	35

[1] Ship voyage from Los Angeles to Hamburg.

TABLE 5.--Transfer and loss of biphenyl in vented and nonvented cartons of lemons in the fourth static test

(Biphenyl expressed in grams per carton; initial application 4.7 grams per carton)

Location of biphenyl	First inspection (after 4 weeks at 39° F.)		Second inspection (after 2 weeks at about 80° F.)	
	Vented carton	Nonvented carton	Vented carton	Nonvented carton
	Grams	*Grams*	*Grams*	*Grams*
Biphenyl sheets.....	1.8	2.5	0.2	0.9
Fruit.....	.1	.1	.5	.7
Lost to air and in carton walls (by difference)...	2.8	2.1	4.0	3.1

According to Farkas and Aman the growth rate of Penicillium cultures on agar diminishes rapidly with increasing concentration of biphenyl in the atmosphere and at 17.5 percent saturation at 25° C. (14 micrograms per liter) the growth rate over a 10-day period was reduced to 50 percent of that in air. A further increase to 37.5 percent of saturation (30 micrograms per liter) reduced growth to about 25 percent of that in air. These values would vary according to the degree of biphenyl sensitivity of the particular strain of Penicillium.

Similar information is needed on the relationship between biphenyl concentration and Penicillium growth and sporulation on citrus fruits at various temperatures.

No information was obtained on the concentration of biphenyl vapor that existed in the carton atmospheres in these experiments. Despite large quantities of sublimating biphenyl, the concentration of vapor in a carton can be expected to be appreciably below

saturation because of absorption by the fruit and the fiberboard in the cartons, and because of diffusion through the fiberboard and the carton vents. As shown in table 5, by far the most important factor in the decrease in effective biphenyl is the loss to the outside air and possibly to the fiberboard, which even in the nonvented cartons amounted to over 80 percent of the biphenyl lost from the sheets. Perhaps this kind of loss could be reduced by decreasing the porosity of the material used in the cartons or by decreasing the size of the vent holes, or both. However, enough carton wall porosity or ventilating holes must be retained to permit the entrance of oxygen to replace at least some of that used in respiration, and to permit the escape of metabolic volatiles. Carton material in current use appears to have enough gas permeability to allow sufficient exchange of oxygen and carbon dioxide to supply the metabolic needs of the fruit. The atmosphere in nonvented cartons containing oranges has been found to have nearly the same oxygen and carbon dioxide concentrations as normal air (2).

Decay Caused by Organisms Other Than Penicillium

The results of the overseas tests agree with previous findings which have shown that biphenyl does not appreciably affect organisms other than Penicillium causing decay in California citrus fruit (7). The decayed fruits were separated roughly between those in which Penicillium species, including digitatum and italicum, caused the decay and those in which decay was caused by miscellaneous other fungi. Only a rough separation could be made because fruits were commonly attacked by more than one organism and personal judgment was involved in trying to determine which kind might have caused the initial infection. The information given in table 1 must therefore be taken only as an approximation. Decay caused by the miscellaneous organisms was not high, nor was it appreciably affected by biphenyl, although the average figures are slightly lower for fruit treated with biphenyl than for the control lots. Sour rot can be an important factor in transit deterioration because of the large amount of soilage it can produce. Since biphenyl does not reduce either decay or soilage caused by this organism, a fungistat or fungicide similar to biphenyl and capable of inhibiting the growth of this fungus would be useful in reducing decay and soilage.

Commercial Nontest Lemon Shipments

No differences in decay or soilage associated with carton venting were noted in commercial lemon shipments on arrival. Reexamination of commercial lots after storage at the harbor was not possible. Both vented and nonvented cartons contained fruit in excellent condition, but both also contained fruit with high percentages of decay or soilage. Carton venting was not related to differences in fruit color in either commercial lots or in the test shipments.

Marked differences existed in the keeping quality of fruit of various brands received from different packing houses. According to the receivers, some brands consistently arrive in excellent condition, whereas others commonly arrive with excessive decay and soilage. These differences have been observed previously by representatives of Market Quality Research Division (5, 9) and others. Differences between brands become especially noticeable when transit conditions are somewhat below standard; for example, when the transit period is especially long because of mechanical or other troubles, or because the ship's schedule was extended in order to take on additional cargo.

European receivers are convinced that average arrival condition could be materially improved by more judicious selection of export fruit.

The effectiveness of biphenyl in controlling decay by Penicillium was generally good. In a few of the test packages, however, decay and soilage were high even though the usual dosage of biphenyl had been provided. Commercial lemon shipments from a few packing houses arrived rather consistently with considerable decay and soilage in spite of what appeared to be the customary dosage of biphenyl. Results obtained by the senior author

in Hamburg suggest that strains of Penicillium having a greater than usual tolerance to biphenyl may be present in one or more lemon packing houses. Fruit from one house in particular arrived in European markets during the season with appreciable Penicillium decay and soilage from dusting. Sound lemons from the test lots shipped from California were inoculated with spores from decayed fruit in these test lots. Other lemons from these test lots were inoculated with spores from decayed fruit of a commercial shipment having an unusually high percentage of decay. The lemons were then wrapped in sheets still strongly impregnated with biphenyl crystals and all enclosed in several layers of polyethylene film. After 6 days at an average temperature of about 65°F., fungus was developing rapidly and had started to sporulate on the lemons inoculated with spores from the commercial lot of decayed fruit. However, there was no perceptible fungus growth and the inoculated areas were firm on the lemons inoculated with spores from decayed fruits from the overseas tests.

DISCUSSION

Rate of cooling was fastest and decay and soilage of the fruit at the final inspection least in the third ship test. Rate of cooling was slowest and decay and soilage highest in the second ship test. The agreement between rate of cooling and percentages of decay and soilage is reasonable, but the fact that the test fruit on the ships was of different origin and that the second shipment was at sea 19 and 21 days longer than the others must be taken into account. The rapid handling of the fruit in the third test in packing and loading aboard ship, plus the rapid cooling on board, undoubtedly helped account for the better condition of fruit in vented cartons compared with the first and second tests. Rapid handling and rapid cooling were important factors in decay control and conserved biphenyl, making it available at destinations where it was needed most urgently. The biphenyl data from the fourth static test support this view.

Less fruit soilage developed in vented than in nonvented cartons when no biphenyl was used.

The use of biphenyl in the packages consistently reduced both decay and soilage caused by Penicillium. Losses from decay and soilage were usually lower in nonvented cartons with biphenyl sheets than in similar vented ones at the final inspection of the test fruit, but a definite recommendation on venting should not be made on the basis of these limited experiments. Much economic importance is attached to carton venting, and several more tests should be made over an extended period of time to arrive at the correct decision. Commercial experience suggests that the carrying quality of lemons may differ greatly from year to year, and it is important that tests be conducted during at least one season in which fruit of poor carrying quality is produced.

Fruit soiled from spore dusting decayed faster after they were sorted during inspection than did clean fruit. Buyers discriminate against soiled fruit that has been cleaned, apparently for good reasons. It is not as attractive as fruit that has not been soiled because the spores cannot be completely removed. Furthermore, buyers assume that re-sorted lots of fruit have a shorter residual storage life than lots that remained clean during transit.

Test fruit remained wet from condensation several days after unloading. No attempt was made to determine whether or not the fruit was injured by this moisture.

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