Blue-green Mold on Citrus

ammonia gas used in citrus packing plants as fumigant for control of blue-green mold on Valencias, navels and lemons

C. N. Roistacher, L. J. Klotz, and I. L. Eaks

Laboratory experiments with anhydrous ammonia—for the control of blue-green decay in injured-inoculated fruit—developed a treatment that provided excellent protection for oranges and lemons. However, tests also revealed that the gas must be applied within the first 24–30-hour storage period to be effective, because at 68°F the green mold—*Penicillium digitatum*—will penetrate approximately one millimeter into the rind, beyond reach of the chemical. Therefore, fruit injured in picking, dumping and loading must be treated promptly to avoid infection.

The early experiments also showed that mixtures of ammonia, used as a fungicide, and ethylene gas, used for degreening, did not interfere with the desired action of either gas.

The laboratory method of ammonia treatment for control of blue-green mold was tried with navel and Valencia oranges and lemons in five different packing houses located in three widely separated citrus areas in California. Test fruits were inoculated and distributed in various boxes throughout the sweat rooms. Fumigation with ammonia began within 24–30 hours after the fruit arrived at the packing house. There was effective decay control and no report of injury on the treated fruit.

Ammonia Gas Fumigation in Commercial Packing Houses for Control of Blue-green Mold Decay

Packing house	Fruit	Cu. ft. in room	Ammonia injected Liters	No. of hrs.	Decay on injured-inoculated fruit	
					Checks %	Ammonia %
Bryn Mawr	Val. Or.	4,400	1,495	10	75	16
Woodlake	Navel Or.	10,000	4,247	9	73	21
Orange Cove	Navel Or.	6,100	1,727	9	88	10
Lindsay	Navel Or.	8,800	2,491	9	51	17
Lindsay	Navel Or.	8,800	3,115	9	75	16
Carpinteria Mutual						
Field boxes	Lemon	1,600	611	6	76	34
Storage boxes	Lemon	1,600	1,178	6	79	15

Ammonia gas is highly sorbed by the surfaces of containers—fiberboard or wood—room, fruit, and by moisture. Successful control of decay is obtained by concentrations of ammonia which are lethal to the spores on the fruit surface and more specifically in injuries, but which are not corrosive to the fruit surface.

A graph of the ammonia concentrations in the air surrounding the fruit during and for some time after the injection is given on the next page. The area bounded by the curve and x-axis is the ammonia index and in this example is 1770; it can be used to compare one ammonia treatment with another. Decay control for this ammonia index is shown in the lower table on the next page. The amount of decay control and rind injury were found to be directly proportional to the magnitude of the ammonia index.

Control of decay without injury is achieved by ammonia indexes of 500 to 3,000. Injury may be expected when the ammonia index is above 3,000.

Concluded on next page

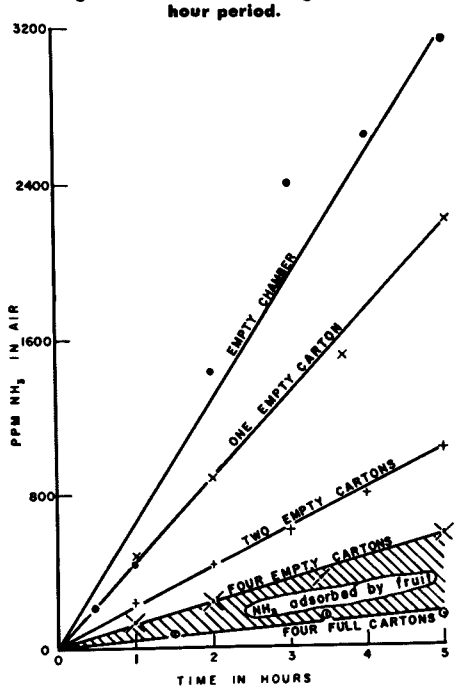
Ammonia treated and untreated injured-inoculated oranges and lemons. 1.2 liter of ammonia was rapidly injected in an eight cubic foot chamber two times daily for four days.

Continued from preceding page

The relative amount of ammonia sorbed by the fruit is small in comparison to that sorbed by fiberboard cartons as shown in the upper graph on this page. Ammonia was introduced into chambers containing 0, 1, 2, and 4 empty cartons and resulting concentrations recorded. The high sorptive capacity of the carton for ammonia gas is evident. Free ammonia in a chamber containing four cartons with fruit was less than with four empty cartons. As much as 90% of the ammonia introduced was sorbed by the cartons, fruit, chamber walls and moisture. Therefore, it is necessary to add sufficient amounts of ammonia to satisfy the sorptive capacity of the containers in addition to that necessary for fungicidal effectiveness.

Ammonia is most effective against spores in a moist environment. Spores falling into a fresh injury are readily killed by ammonia. However, dry spores on the surface of fruit may escape a concentration of ammonia lethal to moist spores. Consequently repeated dosages of the gas are believed to be more effective than single injections, since the spores—because of exposure to moisture—become more susceptible to ammonia.

Sorption of ammonia gas by cartons and orange fruits. Each line shows ammonia concentration in air of an eight-cubic-foot wooden chamber receiving 1.05 liter of ammonia gas over a five-hour period.



Ammonia Treatment of Oranges and Lemons
Two daily one minute injections of ammonia gas for four days in 8-cubic-foot wood chambers holding one box of navel oranges and one box of lemons. Ethylene gas at 500 ppm was injected with the ammonia.

Ammonia gas per injection Liters	% decay		Injury
	Oranges	Lemons	
0 (check) ..	88	54	...
0.57	1	0	None
1.13	0	0	None
2.26	0	0	Buttons brown and loose. No pitting.

Laboratory Tests with 10-hour Injections of Ammonia Gas for Decay Control in Oranges in Cartons

Fruit	Ammonia index	Decay in injured-inoculated fruits		Injury
		Check %	Ammonia %	
Navel ..4,200		68	5	Button darkening and slight wound enlargement.
Navel ..1,770		76	20	None
Val. 2,500		66	5	None
Val. 700		46	1	None
Val. 500		55	9	None

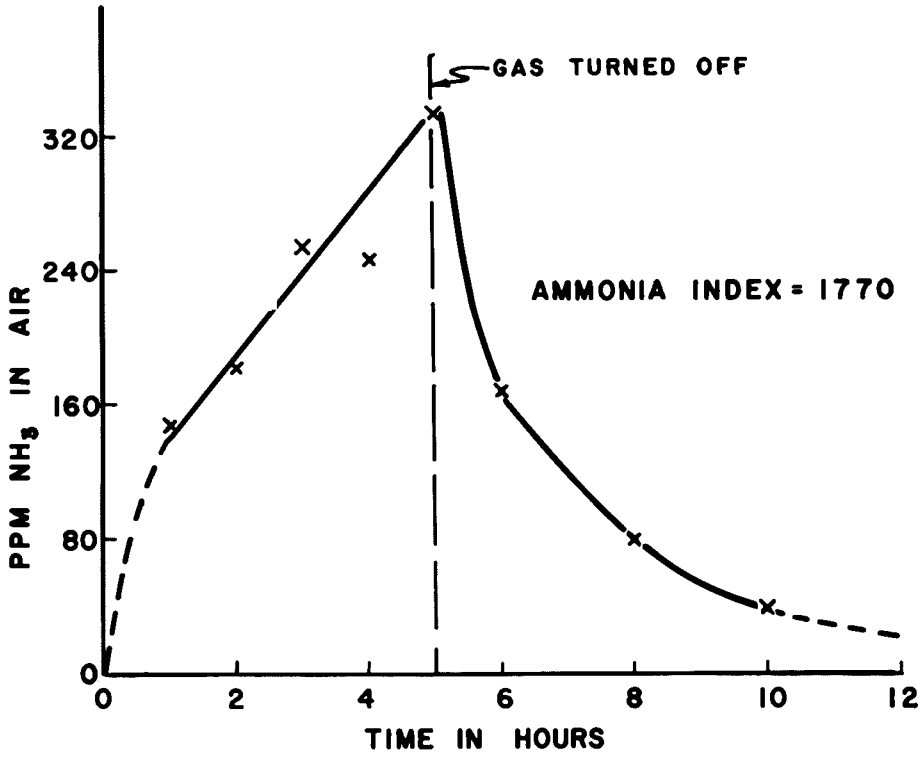
Use of Ammonia

Green-mold decay of citrus fruit develops at a rate proportional to the temperature of the rind. At 68°F, green mold will penetrate approximately one millimeter into the rind in 24–30 hours. At that depth ammonia loses its ability to destroy the infection and stop development of decay. If the fruit temperature averages 60°F, the grace period is about 40 hours and at 50°F, about 80 hours.

Citrus fruit that is picked and held in basements or on the packing house floor for longer periods may have infections which have developed beyond the period for effectiveness of gassing treatments. To prevent this primary infection, fruit can be immersed in a suitable fungicidal solution within the time-temperature periods. However, the immersion treatment is not always possible because some lots of fruit are degreened, others must be preconditioned prior to hot water treatment, and some associations pick ahead in order to take advantage of good picking weather. In such cases the fruit should be treated with ammonia, which can be done in degreening rooms or in enclosures constructed of canvas. Ammonia—at the concentrations used in these trials—has been noncorrosive in those packing houses where it has been in regular use for over a year.

Laboratory experiments at Riverside and field trials in packing houses have shown that an average concentration of 100 ppm—parts per million—of ammonia maintained in the atmosphere for a 9–10-hour period will achieve good control of the blue-green mold of orange and lemon fruit.

Ammonia concentration in air, determined periodically during and after an ammonia injection of 2.12 liters over a five-hour period in room containing 300 cartons of citrus fruit.



C. N. Roistacher is Principal Laboratory Technician in Plant Pathology, University of California, Riverside.

L. J. Klotz is Professor of Plant Pathology, University of California, Riverside.

I. L. Eaks is Assistant Plant Physiologist in Plant Biochemistry, University of California, Riverside.

The above progress report is based on Research Project No. 808.