Effects of STORAGE TEMPERATURE AND HUMIDITY ON LOSS OF WEIGHT BY FRUIT

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EFFECTS OF STORAGE TEMPERATURE AND HUMIDITY ON LOSS OF WEIGHT BY FRUIT

By Arthur W. Wells, senior plant physiologist,
Market Quality Research Division, Agricultural Marketing Service

SUMMARY

The rates of weight loss of several kinds of fruit, stored at various temperatures and humidities, were measured in laboratory tests.

At a constant temperature and for limited periods, the rate of weight loss increased about 50 percent for each 100 percent increase in vapor pressure deficit.

The rate of weight loss increased or decreased with an increase or decrease in temperature, even though the vapor pressure deficit remained constant.

A straight line relationship exists between weight loss and vapor pressure deficit, at a given temperature, when plotted in actual units on simple chart paper.

The loss of weight varied inversely with the size of the fruit.

Softening of oranges, as measured by compression, varied with the quantity of weight lost.

BACKGROUND OF STUDY

Moisture evaporates continuously from fruits during handling and storage. Under some conditions, the loss may be great enough to cause the commodity to shrivel and to impair the flavor and lower the market quality. The rate of evaporation depends upon the nature of the commodity, the elapsed time since harvest, and the temperature, relative humidity, and rate of movement of the surrounding air.

Several investigators have studied the effects of storage environment on the quality of fruit. Bates (1)[1] showed that oranges lost weight much more rapidly during the first 3 or 4 days after harvest than during subsequent storage.

Comin, Junnila, and Ellenwood (2) found that the transpiration values per millimeter of vapor pressure deficit were constant and independent of humidity and temperature for short periods. Comin and Junnila (3) suggested that vegetables going into cool storage should be cooled as rapidly as possible to shorten the time of high vapor pressure deficit between the vegetable and surrounding air. Gac (5, 6) reported that there was an inverse and almost linear relationship between the weight lost by fruits and the relative humidity of the surrounding air, and stated that, because of transpiration, the fruits lost some moisture even in saturated air. Kidd and West (8), Mann (9), Pieniazek (10, 11), A. J. M. Smith (13), and W. H. Smith (14, 15, 16) measured the rate of moisture evaporation from apples under various storage conditions.

The present work was initiated to study the relationship between moisture loss of fruit and vapor pressure deficit, and to obtain information on losses from commodities not previously studied.

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[1] Underlined numbers in parenthesis refer to items in Literature Cited, p. 14.

The data presented should be useful to operators of commercial fruit storage houses. The effects of the relative humidity of the storage rooms on softening and loss of weight of the stored fruit are shown quantitatively. The data emphasize the importance of keeping the relative humidity of fruit storage rooms as high as possible, consistent with other factors which must be considered in good storage practice.

The weight losses shown include that of carbon dioxide evolved in respiration of the fruit, as well as that of moisture lost by evaporation. No correction was made for weight loss due to carbon dioxide because the amount is small in proportion to the weight of moisture lost.

MATERIALS, METHODS, AND EQUIPMENT

The fruits used for these experiments were obtained directly from orchards or packing houses; in the latter case, they were obtained only a few hours after harvest. They were weighed individually and then assembled into lots of approximately equal weight. Two such lots were held in 10-liter glass desiccators (fig. 1) at the same temperature and humidity. The total number of each kind of fruit used in the tests varied from about 100 to 450, except avocados and grapefruit, of which 36 were used. Constant humidity was maintained in the desiccators with glycerine or saturated salt solutions. Small diaphragm pumps connected at the top and near the bottom of the vessels produced a gentle air movement within the desiccators. The air was circulated only enough to maintain uniform atmospheric conditions within the storage container.

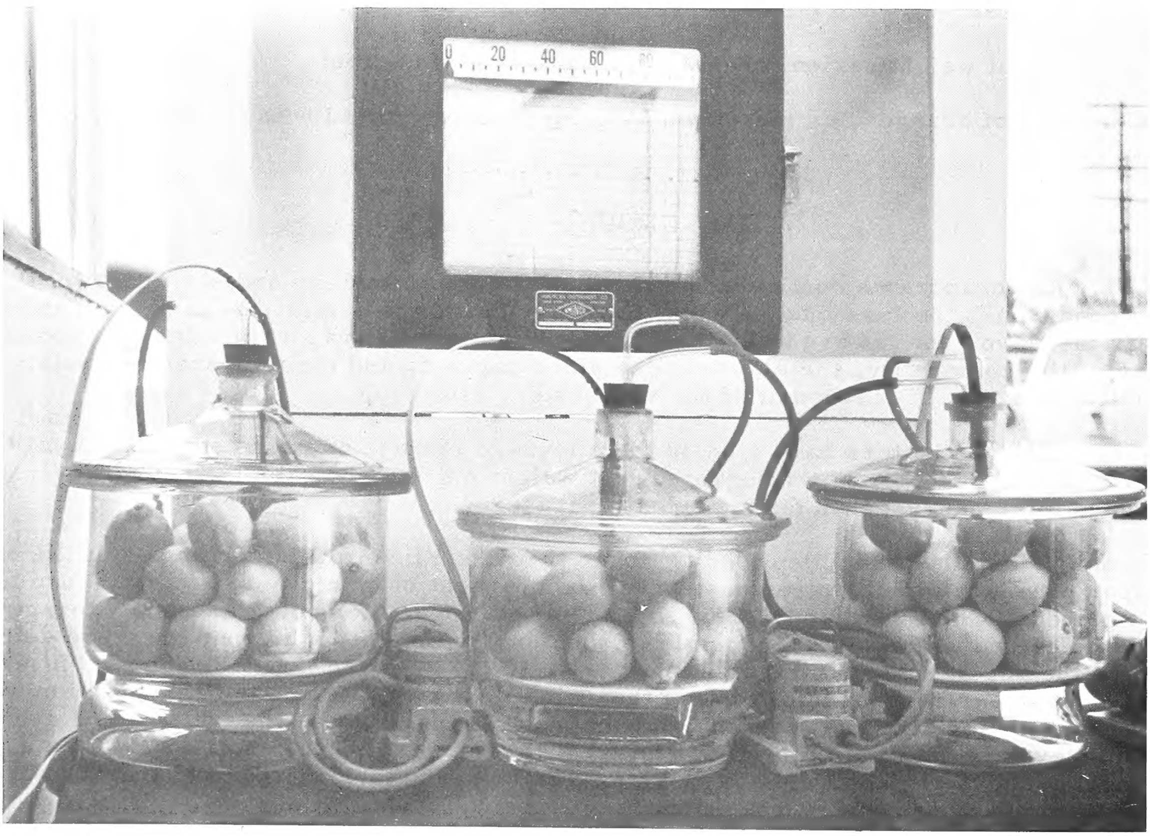

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Figure 1.--Desiccators with fruit, humidity sensing elements, and pumps used for air circulation.

The relative humidity was determined with electric hygrometer sensing elements consisting of polystyrene cylinders wrapped with dual windings of precious-metal wire and coated with a moisture-sensitive compound (4). Changes in the electrical resistance of these hygroscopic films with changes in moisture content of the ambient air were measured in terms of electrical current flowing through the element. Connection from plug-in contacts on the sensing element to a recorder (fig. 1) permitted readings to be taken every 1-1/2 minutes in each container. These readings were converted to percent relative humidity by reference to a chart furnished by the manufacturer of the elements. Temperatures were obtained with recording thermometers. All equipment except the humidity recorder was contained in constant-temperature rooms. Unless otherwise stated, the data on weight loss are expressed in milligrams per 100 grams of fresh weight per day. Tests extended over periods of 6 to 8 days. The graphs showing the relationship of weight loss to vapor pressure deficit are calculated regression lines.

Humidity condition of the atmosphere is expressed as the vapor pressure deficit, which is the difference between actual vapor pressure and the vapor pressure of a saturated atmosphere at the same temperature. The charts show both vapor pressure deficit and the corresponding relative humidity. The relationship between the vapor pressure deficit and relative humidity at two temperatures is shown in figure 2.

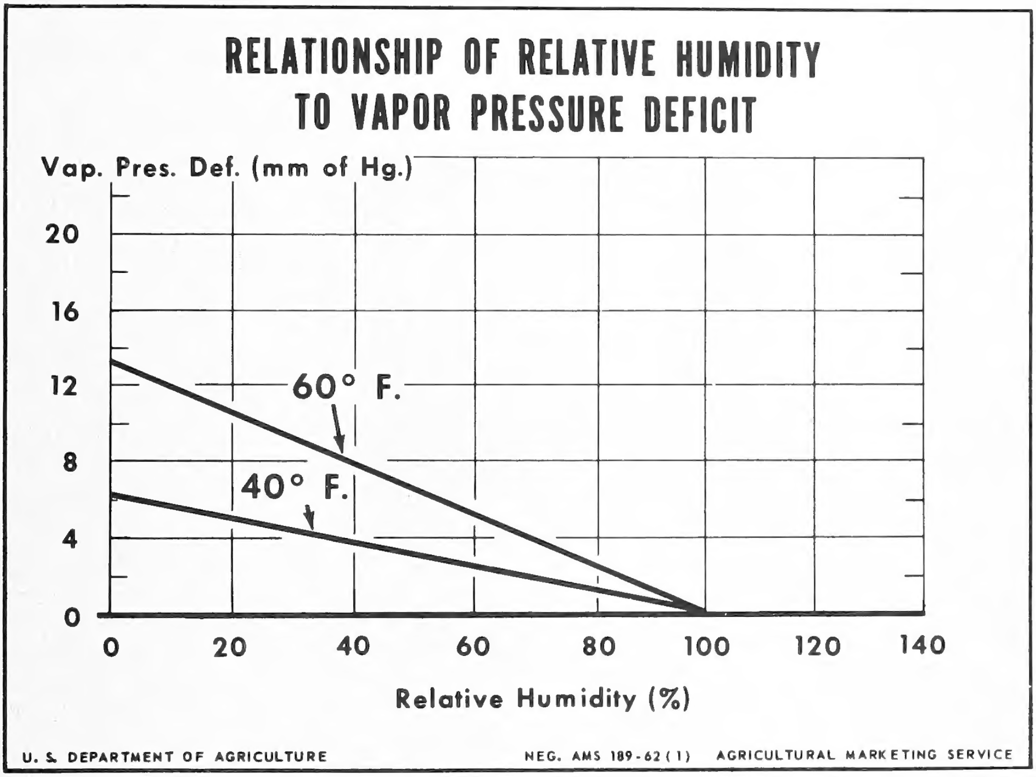

Figure 2

Calculation of Vapor Pressure Deficit

Mann (9) reported that the equilibrium vapor pressure of fruit was 0.98 x the vapor pressure of water at the same temperature. This was confirmed on oranges and lemons during the present investigation. Using this factor, the vapor pressure deficits were calculated as follows:

Vapor pressure deficit = (V x 0.98) - V', where V is the vapor pressure of water at a given temperature and V' is the vapor pressure corresponding to the relative humidity of the air in the storage container at the same temperature.

The compressibility of oranges was measured by an instrument similar to the Cornell pressure tester (7, 12). Essentially, it consisted of a 17-millimeter plunger which rested on the fruit. The upper end of the plunger was connected to a platform upon which a 2-kilogram weight was placed when the equipment was in use. After 15 seconds, readings were made on a scale designed to read in millimeters of compression of the fruit.

The apples used for the experiments were grown in the orchards of the Plant Industry Station, United States Department of Agriculture, Beltsville, Md.; peaches were obtained both from the Plant Industry Station orchards and from commercial growers in South Carolina. The comparisons of waxed with nonwaxed peaches were made on fruit from the same original lot, and the wax was applied with commercial equipment. Oranges, lemons, grapefruit, and avocados were obtained from groves or packing houses in the Pomona, Calif., area.

RESULTS

Apples

Jonathan apples held at 35° F. lost 36 milligrams per 100 grams per day at 90 percent relative humidity and 58 milligrams at 80 percent. Under comparable conditions, Golden Delicious and Grimes Golden lost about twice as much as Jonathans. All three varieties lost weight 1-1/2 to 2 times as rapidly at 85 percent as at 92 percent relative humidity (fig. 3). The Jonathan has a rather heavy coating of natural wax on the surface and the other two varieties a light coating.

Peaches

Some varieties of peaches, if mature but not overripe, can be held satisfactorily for 2 to 4 weeks at 32° F. (17).

The rates of moisture loss from four varieties of nonwaxed peaches were almost identical. The regression line using the data from all four varieties is given in figure 4. The losses varied from 300 milligrams per 100 grams per day at 96 percent relative humidity to about 750 milligrams at 73 percent. The slightly lower rate from commercially waxed fruit from the same original lot was not statistically significant.

At a given vapor pressure deficit, nonwaxed peaches lost weight 1-1/3 to 1-1/2 times as rapidly at 40° F. as at 33°. No comparison at 40° was made on the waxed fruit.

During cooling from 75° to 35° F., peaches lost from 100 to 138 milligrams per 100 grams per hour (table 1, p. 12). This rate was about eight times as high as the hourly rate after the fruit reached storage room temperature (fig. 4).

Lemons

Lemons are frequently stored for several months between harvesting and marketing. Fruit harvested in the light or dark green stage of development is held for a few days at room temperature and then stored at 55° to 58° F. and 85 to 90 percent relative humidity for future shipment.

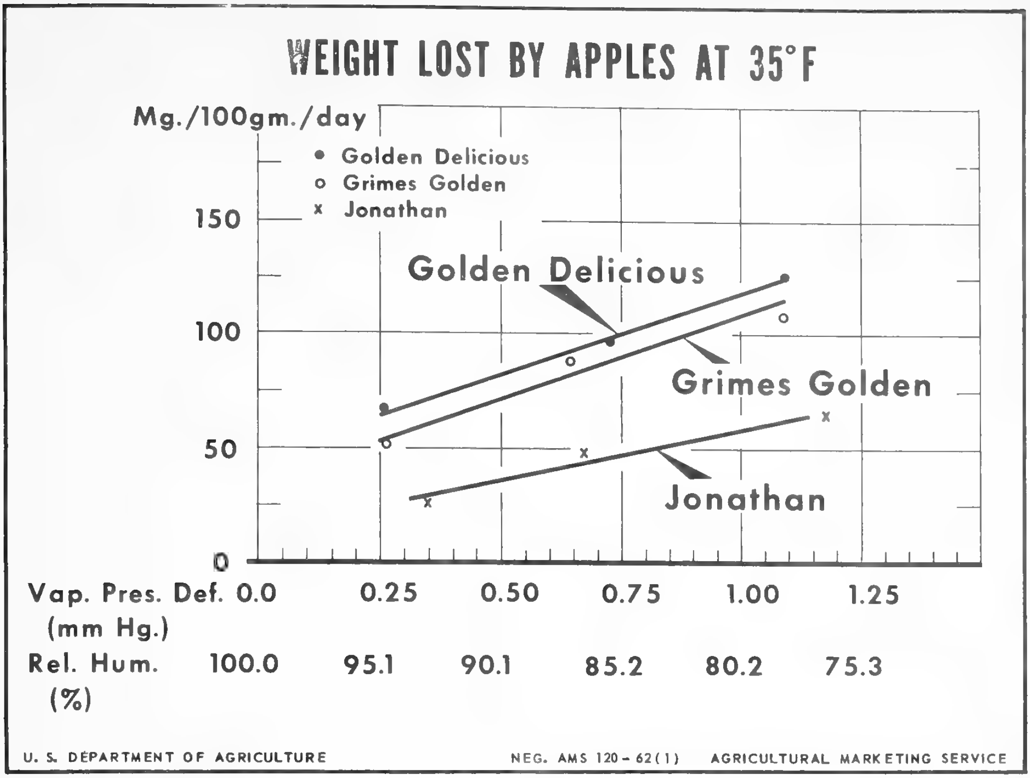

Figure 3

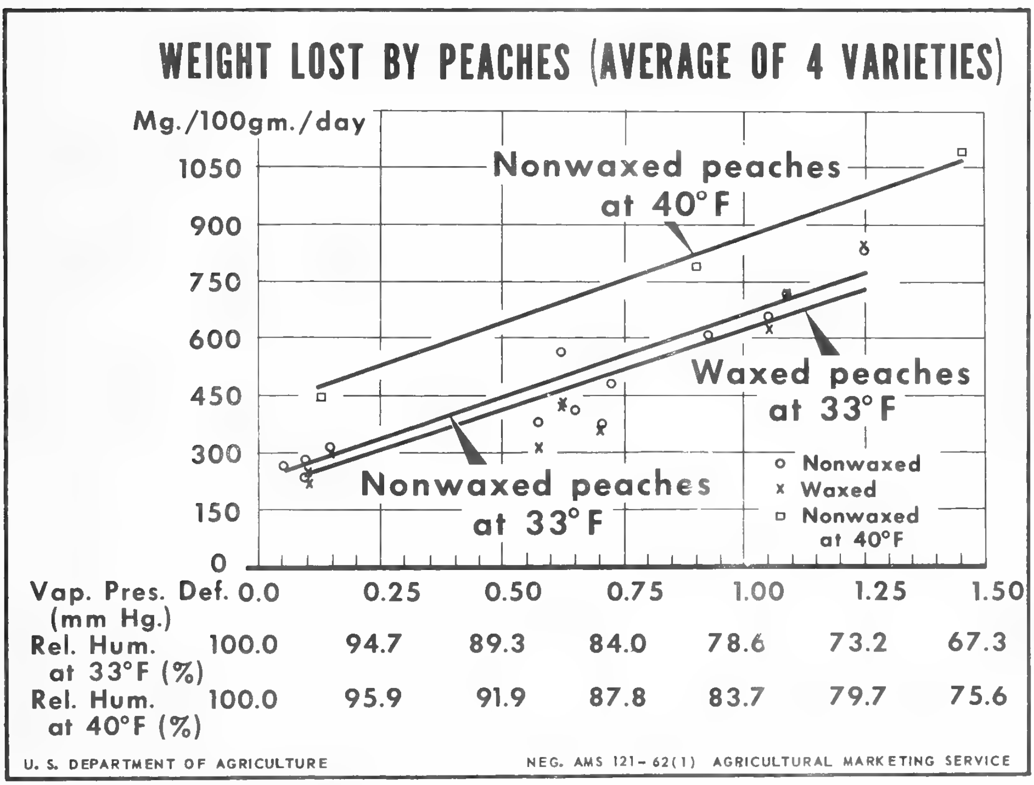

Figure 4

Loss of weight from dark green and yellow Eureka lemons stored at 60° F. at several relative humidities is shown in figure 5. Losses from the dark green fruit varied from approximately 300 to 600 milligrams per 100 grams per day when the relative humidity ranged from 96 to 85 percent. The yellow fruit lost from 250 to 450 milligrams over the same range of humidity.

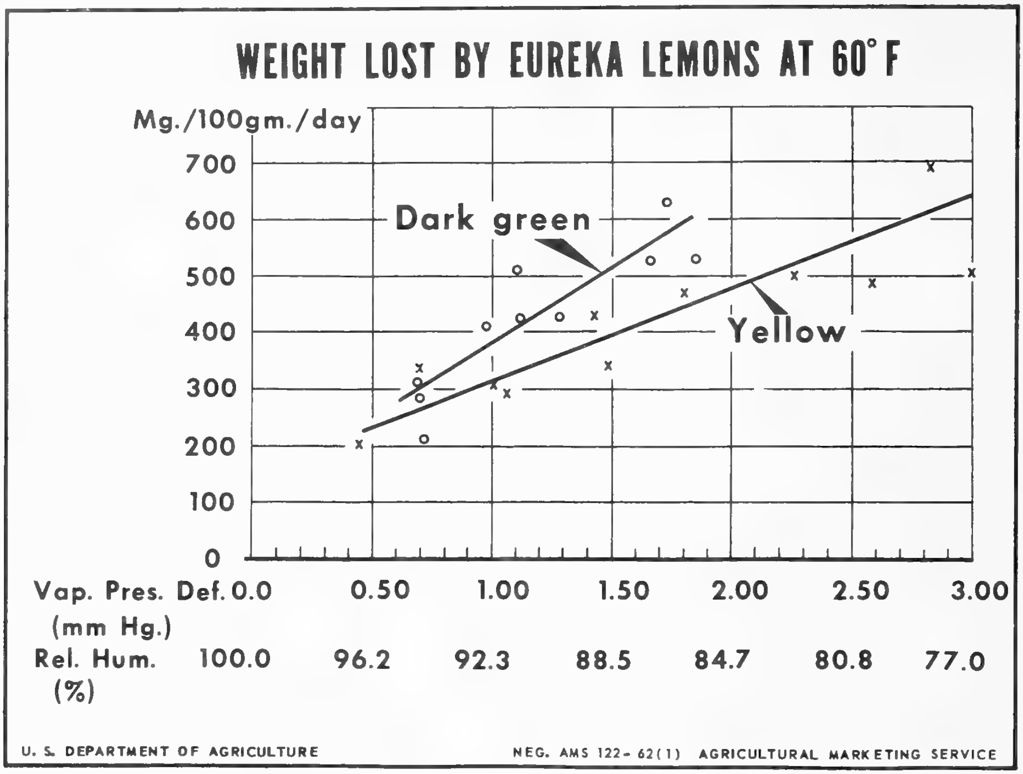

Figure 5

The size of lemons affected the rate of loss, especially at low relative humidity (fig. 6). Small fruits with an average weight of 66 grams lost 1-1/4 to 1-1/2 times as much per unit weight as those weighing 131 grams.

There is a straight-line relationship between weight loss and vapor pressure deficit (at a given temperature) when plotted in actual units on simple chart paper (fig. 6).

Oranges

The rate of moisture evaporation from Washington Navel oranges differed from year to year. At 60° F. and relative humidities from 92 to 80 percent, the average rate of loss from Washington Navel oranges harvested in January 1959 was 1-1/4 to 1-3/4 times as high as that from fruit harvested in January 1958 (fig. 7). Under the same conditions, Washington Navel oranges from the 1958 harvest lost moisture 1-1/3 to 1-1/2 times as fast as Valencia fruit from the 1957 season.

When vapor pressure deficits were held at approximately equal levels, oranges lost weight faster at 60° F. than at 40°. Three lots of Valencia oranges lost an average of 135 milligrams per 100 grams per day at 60° at an average vapor pressure deficit of 1.35 millimeters. At 40°, the average loss was 113 milligrams per 100 grams per day at an average vapor pressure deficit of 1.57 millimeters. Although the vapor pressure deficit was slightly lower at 60° than at 40°, the rate of loss was about 20 percent higher.

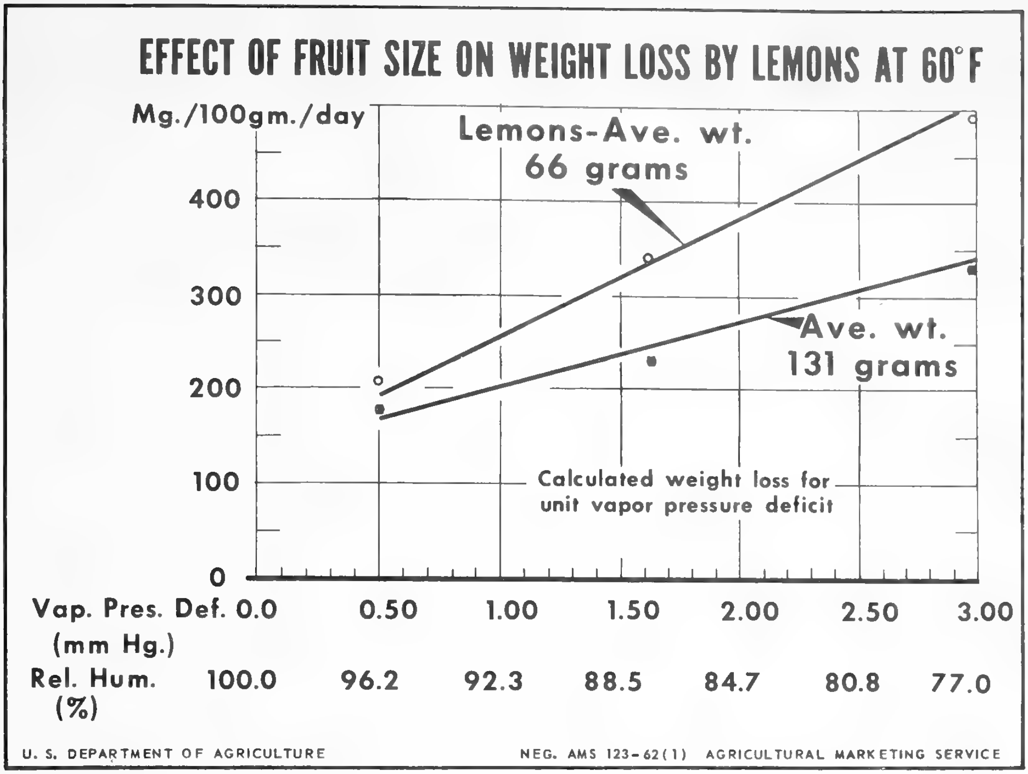

Figure 6

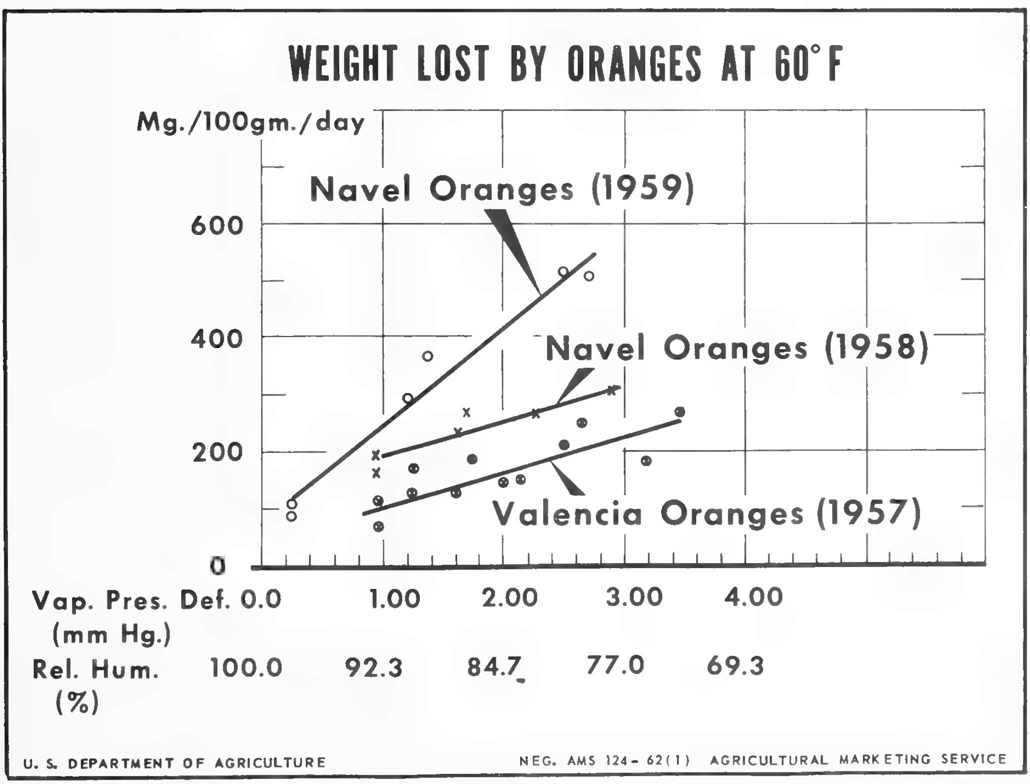

Figure 7

In a test with Washington Navel oranges, the rate at 60° was about 70 percent higher than at 40° (table 2).

The relationship of vapor pressure deficit to weight loss and softening of Washington Navel oranges is shown in table 3. Oranges lost five times as much weight and were considerably softer after holding 15 days at about 85 percent relative humidity and 58° F. than similar oranges held at about 96 percent relative humidity.

Grapefruit

Grapefruit lost weight much less rapidly than other citrus fruits (fig. 8). This difference may be due, in part at least, to the larger size of grapefruit compared to lemons and oranges. At 60° F., the loss varied from about 77 milligrams per 100 grams per day at 91 percent relative humidity to 135 milligrams at 80 percent relative humidity.

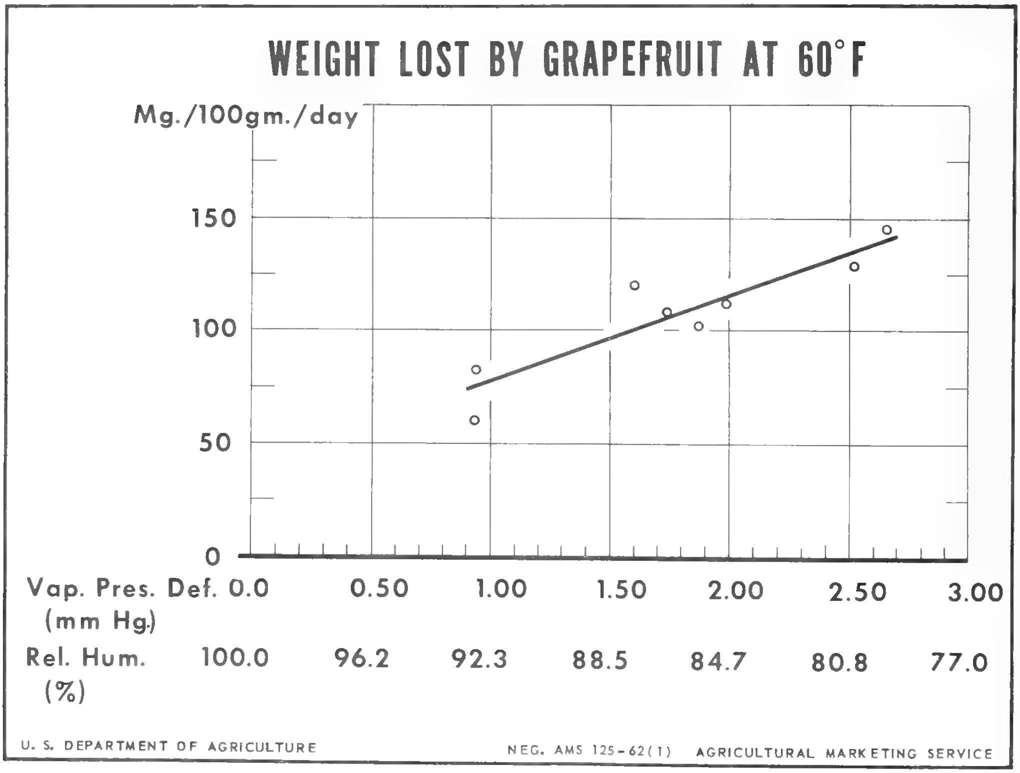

Figure 8

Avocados

The rate of loss of weight by Hass avocados held at 45° F. is shown in figure 9. The loss ranged from about 120 milligrams per 100 grams per day at 95 percent relative humidity to 280 milligrams at 78 percent relative humidity.

Relationship of Weight Loss to Vapor Pressure Deficit

The relationship of vapor pressure deficit to the rate of loss of weight at specified temperatures of all the fruits studied is summarized in table 4. Since the rate of loss varies with temperature, the table is useful only as an indication of the loss of a par-

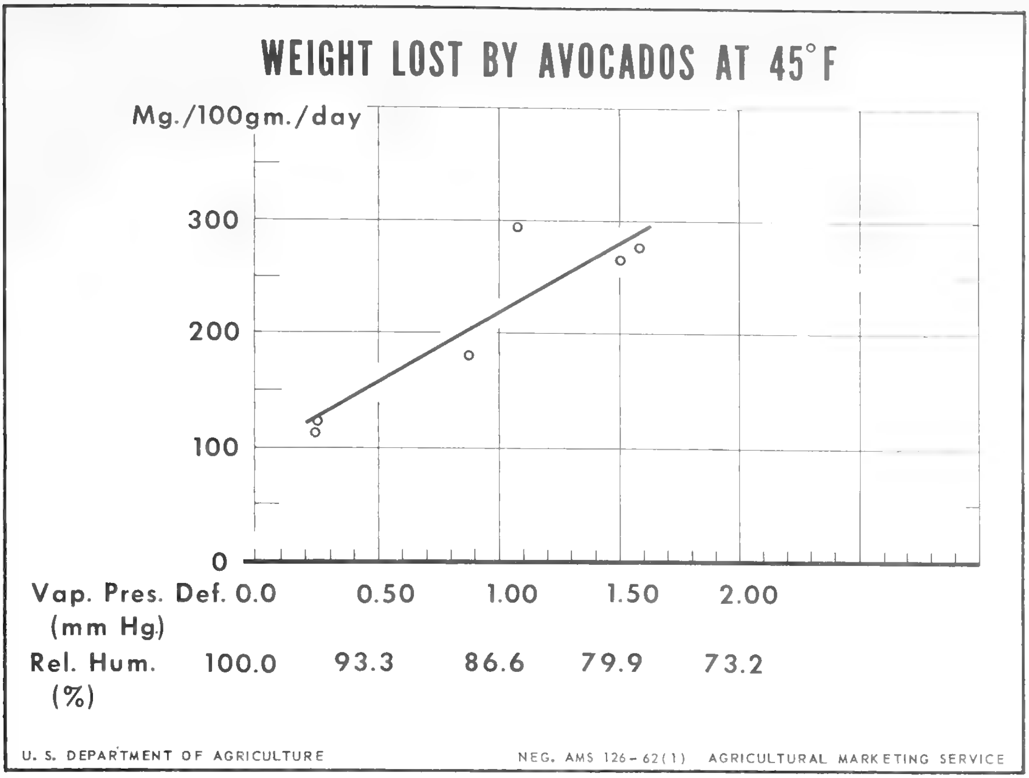

Figure 9

ticular product under specified conditions. With the exception of some of the oranges, the fruits were all held at temperatures close to those used for commercial storage.

The rate of loss at 1 millimeter of vapor pressure deficit averages about 1-1/2 times that at 0.5 millimeter, and the rate at 2 millimeters is about 1-1/2 times that at 1 millimeter.

DISCUSSION

At a given temperature, fruits lose moisture during postharvest handling and storage at rates which vary inversely with the relative humidity and directly with the vapor pressure deficit of the surrounding air. The lower the relative humidity, the higher the vapor pressure deficit and the greater the rate of loss of moisture by the fruit. However, the rate is not constant at a given relative humidity or a given vapor pressure deficit at different temperatures. In this case, more weight is lost by the fruit held at the higher temperature.

In general, small fruits lose weight faster than large fruits of the same kind, as small fruits have more surface area per unit weight than large ones, and hence more opportunity for evaporation. Kinds and varieties of fruit have different rates of moisture loss, depending upon the texture of the fruit and the type of peel.

TABLE 1.--Weight lost by peaches during cooling from 75° to 35° F.

Variety and maturity	Cooling period	Relative humidity	Loss of weight per 100 grams per hour
	Hours	Percent	Milligrams
Triogem (tree ripe)....................	2.0	95	100
	2.0	84	130
Dixie Red (shipping ripe)................	3.5	94	106
	3.5	85	138

TABLE 2.--Weight lost by oranges at 2 temperatures and nearly-equal vapor pressure deficits

Variety	Vapor pressure deficit		Weight lost per 100 grams per day	
	40° F.	60° F.	40° F.	60° F.
	Mm.	Mm.	Mg.	Mg.
Valencia.......................	1.63	1.43	144	166
	1.57	1.30	108	130
	1.51	1.32	88	108
Washington Navel................	1.65	1.51	79	134

TABLE 3.--Relationship of storage humidity to weight loss and softening of Washington Navel oranges held at 58° F.

Relative humidity	Vapor pressure deficit	Weight loss	Compression of fruit
Percent	Millimeters	Percent	Millimeters
95.9	0.26	1.5	4.7
88.9	1.12	5.6	5.9
84.9	1.63	7.5	6.8

TABLE 4.--Weight loss of several fruits at different vapor pressure deficits expressed as milligrams per 100 grams per day

Kind of fruit	Storage temperature	Rate of loss at stated millimeters of vapor pressure deficit			
		0.5	1.0	1.5	2.0
	°F.	Mg.	Mg.	Mg.	Mg.
Apples:					
Golden Delicious	35	82	118	--	--
Grimes Golden	35	72	107	--	--
Jonathan	35	36	58	--	--
Peaches:					
Elberta, nonwaxed	40	640	860	--	--
Elberta, nonwaxed	33	417	591	--	--
Average 3 varieties, nonwaxed	33	436	660	--	--
Average 3 varieties, waxed	33	390	618	--	--
Lemons:					
Eureka, dark green	60	262	385	518	650
Eureka, yellow	60	230	318	395	472
Oranges:					
Valencia, 1957	60	--	100	130	152
Washington Navel, 1957	40	67	117	--	--
Washington Navel, 1958	60	--	190	250	310
Washington Navel, 1959	60	--	290	360	430
Grapefruit:					
Marsh seedless	60	--	77	96	115
Avocados:					
Hass	45	115	219	282	--

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