

TIME AND TEMPERATURE EFFECTS ON PERISHABLES SHIPPED BY AIR*

John M. Harvey
U.S. Department of Agriculture
Fresno

Time and temperature are the major factors controlling the loss of quality in perishable commodities. Shipping perishables by air provides an advantage in time over other modes of transportation, but frequently is accompanied by a disadvantage in respect to temperature. The commodities that are commonly shipped by air -- strawberries, fresh figs, early asparagus, and cut flowers, for example -- are highly perishable and have a low tolerance for adverse temperatures, even for short transit periods.

Temperature Effect on Decay

Temperature has a direct effect on the activity of decay-causing organisms and also on the respiration rates of fruits, vegetables, and ornamentals. The effect of temperature on decay is well illustrated by the results of a test in which strawberries were precooled to 32° F and then held at various higher temperatures for 24 hours (table 1). After the 1-day holding period, there was about twice as much decay in fruit held at 55° as in that held at 34°. There was about 4-1/2 times as much decay at 70° as at 34°.

Temperature Effect on Respiration

The respiration rate is an index of the rate a fruit or vegetable is using up its stored reserves of sugar or other substrates and therefore it is a good measure of shelf life. The higher the respiration rate, the shorter the shelf life of a given commodity. In strawberries (table 2) temperature has a profound effect on respiration rates. The respiration rate of strawberries, expressed in mg. of CO₂ produced in 1 kg. of fruit per hour, is about 3-1/2 times as fast at 50° F as it is at 32° and over 8 times as fast at 70° as at 32°. If we take two temperatures, 36° and 55°, which are fairly characteristic of rail express and air shipments of strawberries, respectively, we see that the respiration rate is about 3 times as fast at 55° as at 36°. Another way of expressing this temperature effect is to say that a 1-day transit period by air at 55° is equivalent to a 3-day transit period by rail at 36°. This illustration is close to the actual transit times by air and rail from California shipping points to the Chicago market.

Strawberry Shipment to Chicago

Now, let's see what actually happened in a shipping test from Salinas to the Chicago market (fig. 1). In this test strawberries were precooled to 36° F. One test lot was shipped by rail express and the other was shipped in an aluminum container which was trucked from Salinas to the San Francisco airport and shipped by air to Chicago.

The temperature in the rail shipment rose slightly during the loading period, but was maintained at an almost constant 38° F during the trip across the country. There was a slight rise in temperature after the car reached Chicago and stood with the fans off before it was unloaded. The berries were in the car a total of 4-1/2 days from time of loading to unloading.

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In the air shipment there was a very rapid rise in temperature to 53° F by the time the fruit reached the airport. Practically all the beneficial effect of pre-cooling was lost, therefore, before the berries were loaded on the plane. The temperatures did not drop during the air portion of the transit period. A total time of 22 hours elapsed between loading the container and delivering it in Chicago.

Let's look at temperatures in the air shipment in more detail (fig. 2). The outside temperatures were quite high, which accounts for the rapid warm-up during the truck movement of the container to the airport. Fruit temperatures were not uniform and fruit near the walls of the container (top and bottom layers) warmed quite rapidly to almost 60° F. The fruit in the center of the load, on the other hand, warmed more slowly, but reached a final temperature of about 53°.

Condition of Berries at the Market

On arrival in the Chicago market the berries in both lots had a good appearance, but a detailed examination showed that individual berries were beginning to decay (table 3). Two types of decay are common in strawberries -- Gray Mold Rot and Rhizopus Rot. In the air shipment, the predominate type was Rhizopus Rot and in the rail shipment the predominate type was Gray Mold. The total amount of decay on arrival was not greatly different in the two lots, 8.8% in the fruit shipped by air, and 10.9% in that shipped by rail. After holding 1 day at 72° F, the berries were again rated for decay. At this examination Gray Mold Rot was about the same in the rail and air shipments, but Rhizopus Rot was more prevalent in the air shipment than in fruit shipped by rail. At this examination the total decay was slightly greater in the air than in the rail shipment. After 2 days at 72° Gray Mold had increased considerably in the rail shipment and Rhizopus Rot had increased in the air shipment. The total amount of decay was about the same in the two lots.

Temperature has a specific and different effect on the activities of each of these two decay organisms. Gray Mold is a cold temperature organism and can grow well at temperatures in the low thirties. Rhizopus is a warm temperature organism and does not grow at temperatures below 50° F. Rhizopus has optimum activity in the low seventies, but it can cause serious damage in the range of 50° to 65°. Knowing the effect of temperature on these two organisms, the type of decay would provide considerable evidence of the transit temperatures, even if recording thermometers were not placed in the loads.

Strawberry Shipment to Washington, D.C.

Another strawberry shipping test was made from Salinas to Washington, D. C. to compare temperatures and market quality in fruit shipped by air and by rail (fig. 3). In this particular test the berries were not adequately precooled and started at a temperature of 46° F. The high initial temperature resulted in higher transit temperatures in both the rail and air shipments than occurred in the previous test. Decay was greater in fruit shipped by rail than that shipped by air because the rail shipment lost its temperature advantage over the air shipment and also had the disadvantage of a longer transit time. Adequate precooling is essential with both modes of transportation.

Asparagus Shipment to New York

Another commodity frequently shipped by air is early asparagus (fig. 4). In this test the asparagus was hydrocooled to 35° to 37° F, loaded in the air container,

trucked to the airport, and shipped by air to New York City. This shipment was made in February and ambient temperatures were quite low. There was a gradual warming of the asparagus in the center of the load to a final temperature of 44°. Warming was somewhat faster in positions near the walls of the container and asparagus in the top layer reached a final temperature of 53°. There was, therefore, a nine-degree difference in temperature at various positions in the container at the end of the 38-hour transit period.

Chrysanthemum Shipment to Florida

Cut flowers are shipped in large volume by air. The flowers are packed in large cartons or hampers that are lined with newspaper or sometimes with fiberglass to help insulate the flowers from either high or low outside temperatures. We studied temperatures last August in chrysanthemums shipped from Mountain View, California, to Orlando, Florida (fig. 5). Comparable lots with initial temperatures near 66° F were shipped by rail express and by air. The temperature of the express shipment dropped rather rapidly to the 40° to 45° range. The express car was refrigerated to Atlanta, Georgia, but at this point the flowers were transferred to an unrefrigerated baggage car. There was a rapid rise in temperature to about 80° after the flowers left the refrigerated car.

The air shipment left at the same time and there was no cooling in transit -- the temperature remained in the 65° to 70° F range as far as Chicago. At this transfer point there was a rapid rise in temperature to 70° to 75° and on arrival in Orlando the temperature was about 75°. A further rise to almost 80° occurred before the flowers were delivered.

How did the quality of the flowers compare in these two shipments? The flowers shipped by rail were slightly wilted on arrival, but recovered when placed in water. They remained salable after holding for 4 days at 45° F and 2 days at 70°.

The flowers in the air shipment had good appearance on arrival and remained salable after holding 4 days at 45° F and 4 days at 70°. The flowers in the air shipment, therefore, had about 2 days more display life than those in the rail shipment.

The obvious problem in shipping flowers by rail was the poor temperature between Atlanta and Orlando. A second test, therefore, was made in which the flowers were shipped by rail to Atlanta and by air from Atlanta to Orlando. In this particular shipment (fig. 5) the flowers were somewhat warmer *initially* and cooled quite slowly during the rail portion of the transit period. There was, again, a rapid rise in temperature at the Atlanta transfer point, but not quite so high as in the previous test. The flowers apparently were held almost 18 hours before making the air connection. The actual time in transit was about the same in the combined rail/air shipment as it was in the all-rail test.

On arrival the flowers were again slightly wilted, but they recovered when placed in water and remained salable for 4 days at 40° F and 3 days at 70°.

Rose Shipment to Florida

Some flowers are shipped with package ice in an attempt to improve transit temperatures and provide protection at transfer points. We made a test shipment

of roses from San Francisco to Orlando last September (fig. 6). The shipper placed 16 pounds of ice in the center of a carton adjacent to the stems. Roses are usually packed with the blooms toward the ends of the cartons. The temperature of the flowers was about 35° F at time of packing. They were held overnight at the packing plant in order to make an early morning plane and left the San Francisco airport about 16 hours from time of packing. The temperature of the stems in the center of the carton remained near the ice temperature, 32° to 35°, for the entire transit period. The temperatures in the ends of the carton adjacent to the blooms rose slightly at the airport in San Francisco (42°). The shipment was taken off the plane at Tampa, Florida, and held overnight to make a connecting flight to Orlando. During this interval the temperature rose from 40° to 61°. There was a slight rise to 62° during the short flight from Tampa to Orlando. The difference in temperature between the ends and center of the carton was about 28 degrees when the shipment arrived. The blooms, which are the most fragile part of the flower, were therefore exposed to the highest temperature.

Carnation Shipment to New York

Freezing is sometimes a problem in flowers shipped during cold weather. Temperatures were studied in carnations shipped from San Francisco to New York in February (fig. 7). In this particular shipment, the flowers remained on the same plane for the entire flight, and were in the 50° to 60° F range for most of the transit period. The temperature in the center of the carton remained fairly constant, but temperatures in the ends of the carton fluctuated considerably. There were noticeable drops in temperature when the plane was on the ground in Chicago and Detroit. Cooling on the ground was probably due to opening the doors for handling other cargo. The transit period in this particular test was about 20 hours.

CONCLUSIONS

1. Quality changes in perishables during short transit periods at temperatures characteristic of air shipments can be close to quality changes in longer rail shipments at low temperature. These changes are the combined effect of metabolic activity and decay and occur much faster at high than at low temperature.
2. Adequate precooling is a "must" in both rail and air shipments. Little or no refrigeration is provided in air shipments and, although rail cars are refrigerated, cooling of some of our packaged commodities is almost impossible during transit.
3. Benefits from precooling can be lost rapidly when commodities are exposed to high ambient temperatures or direct sunlight before loading or at transfer points in air or rail shipments. This suggests the need for refrigerated holding rooms or improved insulation of shipping containers.
4. There are wide temperature variations both in containerized units and cartons for flowers. Work is underway to improve packaging and placement of the ice. Package ice, as presently applied, does little good since the refrigeration is localized and provides little protection for the blooms.

Table 1:--Decay in California strawberries precooled to 32° F and held
at indicated temperatures for 24 hours.

Holding temperature	:	Decay	:	Appearance
<u>°F.</u>	:	<u>Pct.</u>	:	
34	:	6.8	:	Light, bright color; no surface mold
45	:	10.5	:	Few dark berries
55	:	14.8	:	Slight darkening
70	:	30.3	:	Berries generally darkened and slightly desiccated; surface mold on scattered berries

Table 2:--Average respiration rates ^{1/} of strawberries held at indicated temperatures.

Holding temperature	Rate of CO ₂ production	X rate at 32° F
<u>°F.</u>	<u>Mg CO₂/kg./hr.</u>	
32	3,200	1.0
<u>36</u>	<u>4,200</u>	1.3
40	5,100	1.6
50	11,200	3.5
<u>55</u>	<u>13,000</u>	4.1
60	17,900	5.6
70	26,300	8.2
80	41,800	13.1

^{1/} U.S.D.A. Agriculture Handbook #66, 1954.

Table 3:--Decay in California strawberries shipped from Salinas to Chicago, Ill.

October 1958.

Transportation means and examination	Gray Mold Rot	Rhizopus Rot	Total Decay
	Pct.	Pct.	Pct.
Air <u>1/</u>			
Arrival	3.0	5.8	8.8
1 day at 72° F.	26.6	12.6	39.2
2 days at 72° F.	19.6	63.9	83.5
Rail <u>2/</u>			
Arrival	7.5	3.4	10.9
1 day at 72° F.	28.5	3.9	32.4
2 days at 72° F.	72.8	11.6	84.4

1/ Shipped in aluminum container with 20 lbs. dry ice; none remaining on arrival

2/ Shipped full bunker, standard refrigeration, 1% initial salt, 1% at first re-icing, and no further salting; 500 lbs. dry ice in brace.