# Perishables Distribution in the 1970's

## Refrigeration Requirements for Perishables

for 70's

Why produce deteriorates and what you must do to prevent it

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Everyone who stores, ships, or markets fruits and vegetables should try to keep these products in field-fresh condition. Keeping produce fresh for consumers should be the goal. Maintaining good quality after harvest is not simple. Many kinds of produce are highly perishable. Produce is often handled by many people before reaching consumers and transcontinental shipment may be involved. Some food handlers are not sufficiently aware of the need for careful handling and for adequate refrigeration.

Today we think nothing of having a lettuce and tomato salad in midwinter, although the lettuce was shipped from the Imperial Valley of California and the tomatoes may have come from Mexico or the southern tip of Florida. The network of rail lines and highways carrys a continuing supply of food to our tables. Yet waste in marketing fresh produce still runs into million of dollars annually. In 1965, the U. S. Dept. of Agriculture estimated that the annual loss of fruits and vegetables in shipping, unloading, processing, and retailing had a market value exceeding $250 million. 1/ This loss would be greater if losses in storage and those due to a decline in quality were given a dollar valuation.

Why Produce Deteriorates--Why are fruits and vegetables so subject to deterioration? Fruits and vegetables when removed from the plant are composed of living tissues. They continue to respire and carry on certain other life processes. After harvest these processes often result in loss in quality. Respiration is one of the most important In respiration, stored food, such as sugar, is used and the product loses food value. Its quality is being lowered. In respiration, energy is also produced and the excess is thrown off as heat, and heat often has harmful effects. Much of the need for refrigeration to maintain commodity temperatures during storage or transportation can be attributed to respiration. For example, a car of asparagus can produce enough heat of respiration during a cross-country trip to require meltage of 4 tons of ice just to prevent self-heating, with no cooling of the load.

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1/ Anonymous. 1965. Losses in Agriculture. U. S. Dept. Agr., Agr. Hand. 291.

The respiration rate is a good index of the rate of living. Fruits and vegetables that respire the fastest give us the greatest handling problems, as they are the most perishable. Refrigeration is the best method of slowing respiration and other life processes. Strawberries respire about 10 times as fast at 70°F. as at 32°, and sweet corn respires about 8 times as fast at 70° as at 32°, (Table 1). With fresh produce our goal in quality maintenance is to retard the rate of living without stopping the various processes altogether.

Table1. Respiration rate of produce at 32°, 40°, and 70° F.

| | $CO_2$ production (mg./kg./hr.) | | |
|---|---|---|---|
| Product | 32° | 40° | 70° |
| Apples | 3 | 4 | 56 |
| Peaches | 5 | 8 | 72 |
| Strawberries | 15 | 27 | 149 |
| Potatoes | 3 | 6 | 13 |
| Celery | 7 | 11 | 64 |
| Sweet corn | 30 | 43 | 228 |

Another factor in the perishability of produce is that fruits and vegetables are usually well covered with countless micro-organisms, bacteria and mold spores, some of which will cause decay if given the right conditions. The spore load on produce can be demonstrated easily by dipping a specimen in an agar culture and then watching the fungi develop. Deterioration due to decay is probably the greatest source of spoilage during marketing. Refrigeration is the best method of preventing decay because low temperatures control the growth of most micro-organisms.

Prompt precooling after harvest to remove field heat and to retard metabolism is highly desirable for many kinds of produce. This may be accomplished by hydrocooling in ice water (e.g., peaches), by vacuum cooling (e.g., lettuce), or in forced-air precooling rooms (e.g., strawberries). Precooling is of little value if produce is not refrigerated afterwards. After precooling, produce should be moved promptly into storage or into refrigerated cars or trailers.

Refrigeration Benefits--Refrigeration is of value for numerous reasons other than decay control and retarding respiration. Ripening and aging may often be retarded. With apples, 1 day at 70° F. causes as much softening as 2 days at 50°, 4 days at 40°, or 8-10 days at 32°. Peaches soften at a rate of 2 pounds a day at 60°, but only 0.2 pound a day at 32°. With sweet corn 50% of the sugar may be lost in a single day at 70°, while only about 5% will be lost in a day if it is held at 32°.

Loss of vitamins is another form of deterioration in which refrigeration plays a key role. Freshly harvested asparagus will lose 50% of its vitamin C content in 1 day at 68° F., whereas it takes 4 days at 50° or 12 days at 32° to lose this amount.

Many color changes associated with aging can be delayed by refrigeration. The yellowing of celery, cabbage, and broccoli are examples. Broccoli may show some yellowing in 1 day on a non-refrigerated counter, while in a refrigerated display case broccoli will remain green at least 3-4 days.

The relationship between temperature and rate of deterioration varies considerably among commodities and diseases. However, a reasonably accurate generalization, assuming a deterioration rate of 1 at 30° for a fruit such as apples, is shown in Table 2. With certain exceptions, the best temperature to slow down deterioration resulting from a fruit's living processes or from pathogenes is the lowest temperature that can safely be maintained without freezing the commodity. This would be 1 to 2 degrees above the freezing point of the fruit or vegetable in modern storage plants. Actual freezing of produce must be avoided as ice crystal formation within cells is injurious.

Table 2. Approximate relationship of temperature and deterioration rate due to physiological processes and microorganisms

| Temperature ° F. | Deterioration rate |
|---|---|
| 68 | 8-10 |
| 50 | 4-5 |
| 41 | 3 |
| 37 | 2 |
| 32 | 1.25 |
| 30 | 1 |

Loss of moisture with consequent wilting and shriveling of produce is perhaps the most obvious way in which freshness is lost. Here again refrigeration is beneficial in reducing moisture loss, because the water-holding capacity of air decreases as the temperature is lowered. Produce will lose moisture to the surrounding air almost anytime the humidity of the air is less than saturated. When one realizes that most fruits and vegetables are composed of from 80 to 95% water, it is easier to understand how they can wilt and shrivel so readily. Moisture losses can be minimized by lowering the air temperature, by raising the relative humidity, by reducing air movement, and by protective packaging.

High relative humidities of 85 to 95% are recommended for most perishable horticultural products to retard softening and wilting from moisture loss.

A few exceptions, such as dry onions, garlic, dates, pumpkins and winter squash, are listed in Tables 3 and 4.

Recommended Refrigeration--Refrigeration requirements for specific fruits and vegetables are so varied that generalizations are difficult. The majority, however, maintain their harvest freshness longest in storage, in transit, and in wholesale warehouses if stored at 32° F. and 90% relative humidity. Tables 3 and 4 list the recommended storage requirements for many kinds of fresh produce. These are optimum temperatures to minimize deterioration. During food distribution, temperatures a few degrees higher than these recommendations for brief periods will not unduly increase spoilage.

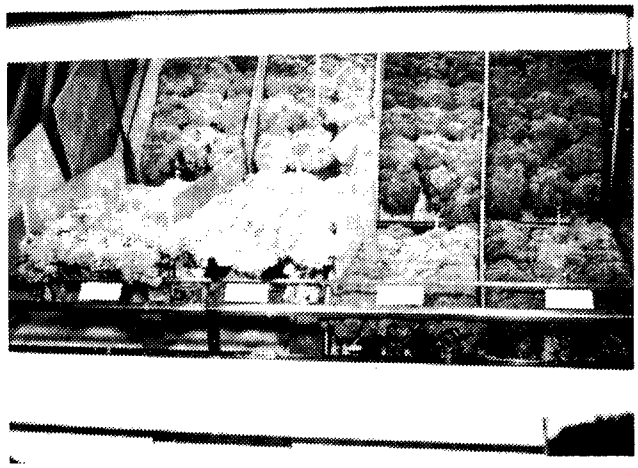
A useful rule-of-thumb to minimize deterioration is to hold cool-season vegetables at temperatures just above their freezing point but hold warm-season vegetables and tropical fruits just above 50° F. Cool-season vegetables include broccoli, celery, cabbage, carrots, lettuce, and cauliflower. For these vegetables the recommendation is cool quickly and keep cold. Warm-season vegetables include tomatoes, cucumbers, squash, eggplant, okra, melons, green beans, and sweet potatoes. They grow best under warm conditions. These warm-season vegetables and most tropical fruits are subject to chilling injury, which often appear after removal from chilling temperatures, include internal breakdown, surface pitting, increased decay, and failure to ripen properly.

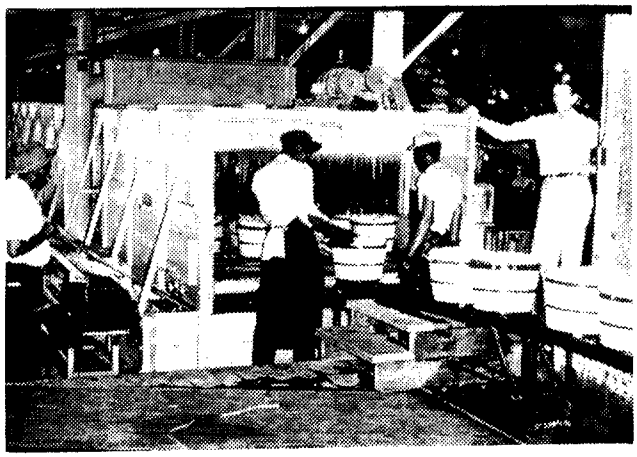
Table 3. Recommended temperature and relative humidity for fresh fruits in commercial storage.

| Commodity | Temperature (° F) | Relative Humidity (%) |
|---|---|---|
| Apples 1/ | 30-38 | 90 |
| Apricots | 31-32 | 90 |
| Avocados 1/ | 40-55 | 85-90 |
| Bananas | 56-58 | 90-95 |
| Berries | 31-32 | 90-95 |
| Cherries 1/ | 30-32 | 90-95 |
| Cranberries | 36-40 | 90-95 |
| Dates 1/ | 0 or 32 | 75 or less |
| Figs, Fresh | 31-32 | 85-90 |
| Grapefruit | 50-60 | 85-90 |
| Grapes | 31-32 | 90-95 |
| Lemons 1/ | 38-55 | 85-90 |
| Limes | 48-50 | 85-90 |
| Mangos | 55 | 85-90 |
| Oranges 1/ (Calif. & Ariz.) | 38-44 | 85-90 |
| Oranges (Fla. & Texas) | 32 | 85-90 |
| Peaches & nectarines | 31-32 | 90 |
| Pears | 29-31 | 90-95 |
| Persimmons | 30 | 90 |

1/ Variety differences exist. See U. S. Dept. Agr., Agr. Handbook No. 66 for further information.

| Commodity | Temperature ( °F) | Relative humidity ( % ) |
|---|---|---|
| Pineapples[1]/ | 45-55 | 85-90 |
| Plums & prunes | 31-32 | 90-95 |
| Pomegranates | 32 | 90 |
| Tangerines | 32 | 85-90 |





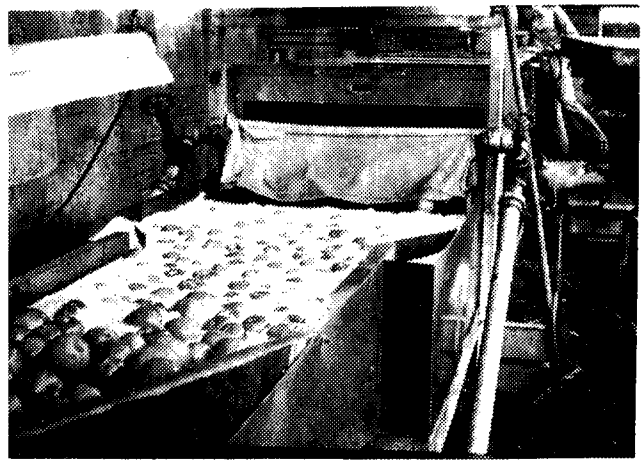


Table 4. Recommended temperature and relative humidity for fresh vegetables in commercial storage. [1]

| Commodity | Temperature (° F) | Relative humidity (%) |
|---|---|---|
| Artichokes | 32 | 90-95 |
| Asparagus | 32-36 | 95 |
| Beans, green | 40-45 | 90-95 |
| Beans, lima | 32-40 | 90 |
| Beets | 32 | 95 |
| Broccoli | 32 | 90-95 |
| Brussel sprouts | 32 | 90-95 |
| Cabbage | 32 | 90-95 |
| Carrots | 32 | 90-95 |
| Cauliflower | 32 | 90-95 |
| Celery | 32 | 90-95 |
| Corn, sweet | 32 | 90-95 |
| Cucumbers | 45-50 | 90-95 |
| Eggplant | 45-50 | 90 |
| Lettuce & endive | 32 | 95 |
| Melons, cantaloupes | 32-40 | 85-90 |
| Melons, other | 45-50 | 85-90 |
| Mushrooms | 32 | 90 |
| Okra | 45-50 | 90-95 |
| Onions & garlic | 32 | 65-70 |
| Onions, green | 32 | 90-95 |
| Peas, green | 32 | 90-95 |
| Peppers, sweet | 45-50 | 90-95 |
| Potatoes, early-crop [2] | 40-50 | 90 |
| Potatoes, late-crop [3] | 38-40 | 90 |
| Pumpkins | 50-55 | 70-75 |
| Radishes | 32 | 90-95 |
| Rhubarb | 32 | 95 |
| Spinach & kale | 32 | 90-95 |
| Squashes, winter | 50-55 | 50-75 |
| Squashes, summer | 45-50 | 90 |
| Sweet potatoes | 55-60 | 85-90 |
| Tomatoes, mature-green | 55-60 | 85-90 |
| Tomatoes, firm-ripe | 45-50 | 85-90 |
| Turnips, rutabagas | 32 | 90-95 |

[1] Some differences due to maturity, variety, intended use, or region of production exist. Consult U. S. Dept. Agr., Agr. Handbook No. 66 for further details.

[2] Temperatures near 70° F. are recommended for chip manufacture.

[3] Temperatures of 50-55° F. are recommended for chip manufacture.

Tomatoes are one of the cold-sensitive vegetables that have definite temperature requirements. Mature-green tomatoes do not tolerate temperatures below 55° F. for more than a few days without showing subsequent chilling injury. Desirable temperatures for long-distance shipment of tomatoes are in the range of 55° - 65°. These temperatures will permit some ripening of the fruit to take place enroute. After arrival, temperatures of 65° - 70° are commonly used for ripening tomatoes. Tomatoes will not ripen normally at temperatures above 80°.

Desirable transit temperatures for fresh fruits and vegetables are usually similar to those recommended for storage. For produce that keeps best at 32° F., thermostats in mechanically refrigerated vehicles should be set at 34°. However, pears for immediate distribution should be shipped at 45° - 55° so that they will ripen somewhat in transit.

Proper refrigeration in wholesale warehouses is vital to maintain top quality in produce. Wholesalers should provide 32° F. storage for about half the produce they handle. Enough refrigeration capacity should be installed to maintain a year-around temperature of 32° and a relative humidity of 90%. Higher temperatures and lower humidities will accelerate quality loss and increase wastage. Neither desirable air temperatures nor humidities can be maintained if excessive air exchange occurs between cold storage rooms and warmer areas. Operators should consider the use of air curtains when doors to the cold room must be opened often, or for prolonged periods.

While not all fresh fruits and vegetables should be stored at 32° F. in wholesale warehouses, controlled storage conditions are desirable for all. Some wholesalers now provide controlled temperature in their general storage areas. The best temperature for this area is 50°. This temperature is satisfactory for produce subject to chilling injury and for short storage of potatoes and onions. Bananas and green tomatoes require special ripening conditions. Bananas are ripened to meet schedules at 58° to 68°; tomatoes at 55° to 70°.

It is impossible to classify all fruits and vegetables into two groups (32° and 50° F.) for wholesaling and be completely accurate. However, this is a useful grouping for persons who do not have a wide selection of controlled-temperature rooms. Optimum storage requirements and transport recommendations for each kind of produce are listed in U. S. Department of Agriculture Handbooks No. 66 and No. 195.[2/]

Check Temperatures -- People responsible for produce should make frequent use of thermometers. Product temperatures should be taken periodically in bulk containers at various locations. It is short-sighted to rely on just one or two aisle thermometers to evaluate produce temperatures. And thermometers of good quality are essential; accurate temperatures cannot be expected from a poor one.

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[2/] For sale at $1.00 each from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402

Storage and Shipping Mixed Commodities--At times it may be necessary to store or ship different products together. This may or may not be safe. With some products there is a cross-transfer of odors. For short periods, as in distribution to retail stores, mixed loading usually is not harmful, but operators should be aware of possible harmful combinations.

Deciduous fruits can generally be stored or shipped together if they have the same temperature requirements. Recently, several mixed loads of grapes and plums were shipped from California and the plums were rejected on arrival. The cars inadvertently, were fumigated with sulfur dioxide which is a common practice to control decay of table grapes, but the sulfur dioxide severely damaged the plums. Combinations that should be avoided in storage rooms are apples or pears with celery, cabbage, carrots, potatoes, or onions; celery with onions or carrots; and citrus fruits with any of the strongly scented vegetables. Pears and applies acquire an earthy taste and odor when stored with potatoes. Also, odors from apples and citrus fruits are readily absorbed by meat, eggs, and dairy products. It is recommended that onions, nuts, citrus fruit, and potatoes each be stored separately.

Volatiles such as ethylene, which are emitted by some products, may be harmful to others. Lettuce and carrots may be damaged by the ethylene given off by apples, pears, and numerous other fruits. Ethylene stimulates ripening of many fruits and vegetables. This ripening effect is negligible at low temperatures (e.g., $32^{\circ}$ F.), but may be important at higher temperatures. For this reason, products such as cucumbers, peppers, and acorn squash, in which retention of green color is desirable and which need to be stored at $45^{\circ}$ - $50^{\circ}$, should not be stored with apples, pears, tomatoes, or other ethylene-producing crops. Much more information is needed on advantages and disadvantages of storage or transport of mixed commodities.

Summary--Refrigeration requirements of fresh produce were reviewed briefly. Admittedly, some of the temperature and environment requirements of different commodities do not coincide with conditions under which mixed loads are handled and shipped. Assuming that fruits and vegetables are harvested with good quality, the use of desirable temperatures is most important in preventing deterioration. In addition, use of various supplements to refrigeration will help insure good quality for the consumer. Requirements for quality maintenance are listed below:

1. Harvest at optimum maturity and quality
2. Precool promptly to remove field heat if necessary
3. Provide adequate refrigeration throughout marketing
4. Provide high relative humidity to minimize moisture loss
5. Handle carefully to avoid mechanical injury
6. Handle rapidly to minimize deterioration
7. Provide protective containers and packaging
8. Use approved chemical, heat, or modified-atmosphere preservative treatments.

Obviously, these requirements are becoming quite well known. Each year more produce arrives at our supermarkets with excellent quality to please the shopper.

The illustrations on pages 108, 112 and 113 are from slides used by Dr. Hardenburg. These and others are available with text in film strip No. C 48 (Revised July 1968) Federal Extension Service, U. S. Department of Agriculture, Washington, D. C. 20250.