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Postharvest Institute for Perishables

Workshop on Transportation and Handling Techniques for Horticultural Produce

Report to
ASEAN Food Handling Bureau,
USAID/Bangkok, and
USAID/Manila

by

Dr. Miguel A. Jiménez
for the
Postharvest Institute for Perishables

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Dr. Miguel A. Jiménez
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Postharvest Institute for Perishables
University of Idaho
Moscow, Idaho 83843
U.S.A.

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I. Executive Summary

USAID/Manila, in Cable Manila 10721, requested that the Postharvest Institute for Perishables provide technical assistance to the Food Handling Bureau of the Association of Southeast Asian Nations in the presentation of a workshop on transportation and handling techniques for horticultural produce. In response to this request Dr. Miguel Jiménez, a private consultant, attended the workshop in Bangkok, Thailand from June 5 to 8, 1983 and presented the two papers in this report.

The following numbers of students were in attendance at the workshop:

Indonesia	-	5
Malaysia	-	6
Philippines	-	7
Singapore	-	3
Thailand	-	14

In addition, from the ASEAN Food Handling Bureau there were:

Dr. Santi Grachangnetara
Dr. P. Kumaraguru
Mr. Vorachak Nachiengtung

At the conclusion, Dr. Kumaraguru, the organizer and coordinator, expressed satisfaction with the conduct of the workshop.

II. Workshop on Transportation and Handling Techniques for Horticultural Produce

A. ROLE OF TEMPERATURE AND RELATIVE HUMIDITY IN STORAGE OF FRUITS AND VEGETABLES

Perishable crops, especially fruits and vegetables, play an important role in the diet of many people in the tropics, providing minerals and vitamins and adding flavor, color, and variety to what would otherwise be a monotonous diet. They also contribute protein and calories (NRC, 1981).

Comparatively little information is available on postharvest losses in fruits and vegetables. Estimated figures obtained from FAO (1977) and other sources are shown in Tables 1 and 2.

Fresh commodities continue to carry on most of the life processes that existed before harvest. They respire and in doing so use up oxygen, give off carbon dioxide and generate heat. Changes that take place in the cell wall composition and structure of fruits result in their softening. Green color gradually gives way to yellow as chlorophyll is destroyed, and several other changes related to pigments, acid content, starch content, and volatile composition also occur after harvest.

Table 1. Fruit Losses in Less Developed Countries*

Commodity	Estimated Loss in %
Apples	14
Avocados	43
Bananas	20 - 80
Citrus	23 - 33
Grapes	27
Papayas	40 - 100
Peaches, Apricots, Nectarines	28
Raisins	20 - 95

*Adapted from FAO (1977)

Table 2. Vegetable Losses in Less Developed Countries*

Commodity	Estimated Loss in %
Cabbage	37
Cauliflower	49
Lettuce	62
Onions	16 - 35
Plantain	35 - 100
Tomatoes	20 - 50

*Adapted from FAO (1977)

Fresh fruits and vegetables are living tissues that continue their metabolic processes at much higher rates than the dry, dormant grains of durable crop products. From the study of some fruits, it has been found that ripening begins either in the field or after harvest and that hormones trigger the ripening process by stimulating the synthesis of enzymes of one kind or another. The changes that take place during ripening are subsequently replaced by the processes of aging (senescence), which set in and cause the fruit to become overripe and finally worthless. We may say that some changes are desirable, but most of them are undesirable from a consumer's standpoint.

Products' requirements for maximum postharvest life vary among groups of commodities because of their differences in morphological structure (roots, stems, leaves, flowers, fruits) and in general physiology.

Although the aim of this paper is to discuss the role of temperature and relative humidity in storage of fruits and vegetables, it is important to understand the biological and environmental factors that cause deterioration.

BIOLOGICAL FACTORS

1. Respiration. Respiration is the overall catabolic process that causes organic materials (carbohydrates, proteins, and fats) to break into simple end products with release of energy.
2. Ethylene. Ethylene is a product of plant metabolism produced by all tissues of higher plants and by some microorganisms. Ethylene is considered the natural ripening and aging hormone and is physiologically active in trace amounts (0.1 ppm).

3. Transpiration. Transpiration or water loss is another cause of deterioration since it results in loss of weight, changes in texture and in appearance such as wilting and shriveling.

ENVIRONMENTAL FACTORS

There are environmental factors involved in deterioration. Among those which play the most significant roles are the following:

1. Temperature. Temperature affects the respiration rate of the commodity, which in turn accelerates or delays the biological reactions that cause deterioration. For each increment of 10°C above optimum temperature, the rate of deterioration increases by two- or three-fold, as shown in the table below.

Table 3. Effect of Temperature on the Rate of Deterioration

Temp. (°C)	Relative Velocity Of Deterioration	Relative Shelf life	Loss per Day (%)
0	1.0	100	1
10	3.0	33	3
20	7.5	13	8
30	15.0	7	14
40	22.5	4	25

Source: Plant Science Syllabus, University of Calif. 1982

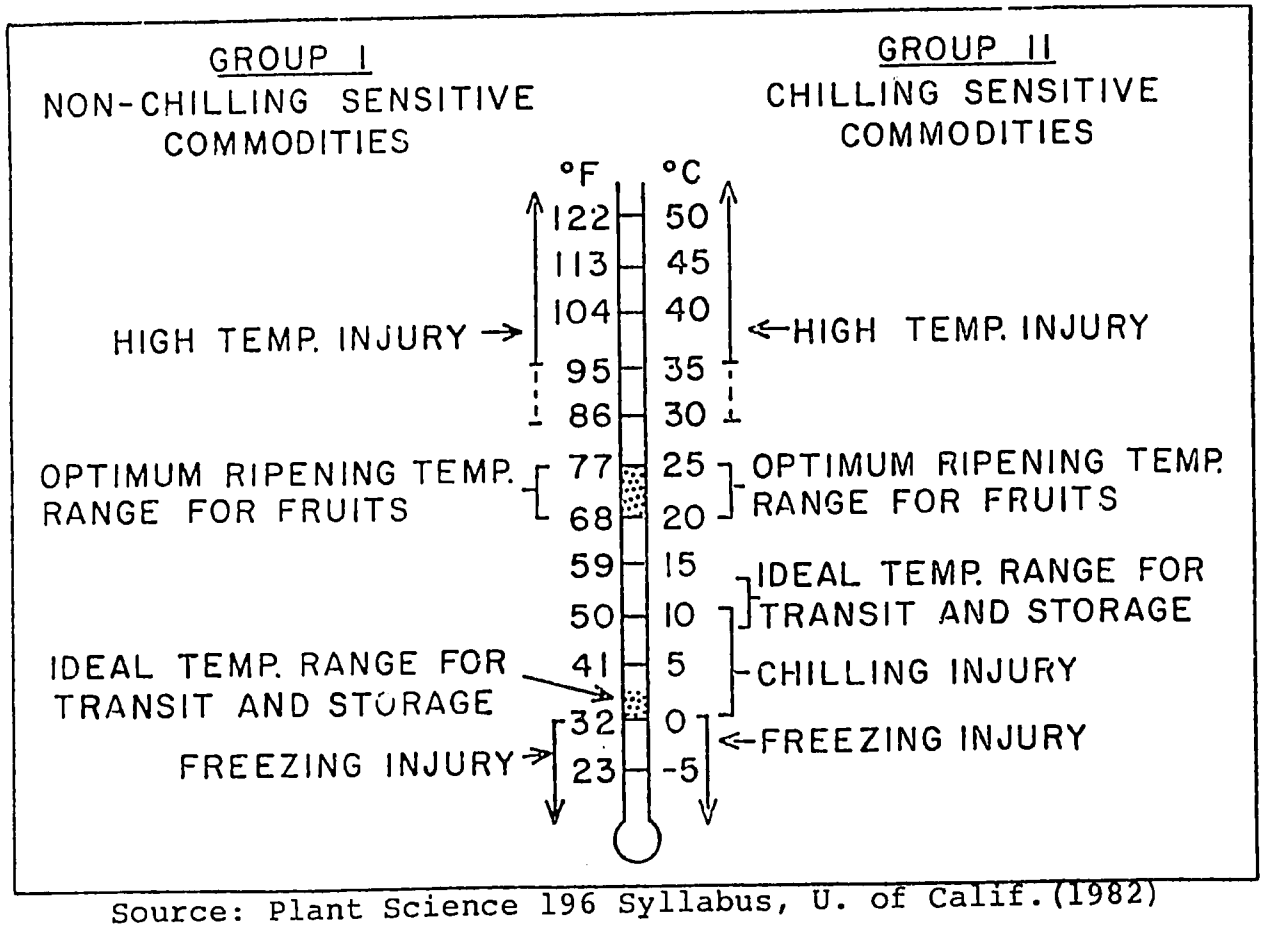
Exposure to undesirable temperatures results in physiological disorders such as freezing injury, chilling injury or heat injury depending on the temperature to which the commodity is exposed. Figure 1 illustrates the effects of temperature on shelf life. Perishables are divided into two groups according to their temperature tolerance.

2. Relative humidity. Relative humidity is the ratio of vapor pressure of the water in saturated air at the same dry bulb temperature. The quality of horticultural products is affected by relative humidity in the ambient air.

3. Other factors. Other factors involved in deterioration of fruits and vegetables are:

   a) Atmospheric composition. This refers to reduction of oxygen and elevation of carbon dioxide whether intentional (modified atmosphere storage) or unintentional.

FIGURE 1. Effects of Temperature on Storage Life of Fruits and Vegetables (Group I and Group II).



Source: Plant Science 196 Syllabus, U. of Calif. (1982)

GROUP I

Apples*
Apricots
Bush berries
Cherries
Figs
Grapes
Nectarines
Peaches
Pears
Persimmons*
Plums
Prunes
Strawberries
Artichokes
Asparagus
Beans, lima
Beets
Broccoli
Brussels sprouts
Cabbage
Carrots
Cauliflower
Celery
Corn, sweet
Garlic
Lettuce
Onions
Peas
Radish
Spinach
Turnips

*(Some varieties are chilling sensitive).

GROUP II

Avocados
Bananas
Cherimoya
Citrus
Feijoa
Guava
Mangoes
Olives
Papayas
Passion fruit
Pineapples
Sapota
Beans, snap
Cucumbers
Eggplant
Muskmelons
Okra
Peppers
Potatoes
Pumpkins
Squash
Sweet potatoes
Tomatoes
Watermelons

b) Exposure to light. This should be avoided in the case of potatoes because it results in greening due to formation of chlorophyll and/or solanine, which is toxic to humans.

c) Chemical compounds. Various kinds of chemicals, such as fungicides and growth regulators, when applied to the commodity affect deterioration.

TEMPERATURE MANAGEMENT

Temperature management is the most important tool that we have to extend shelf life of fresh horticultural commodities. Protection of fresh fruits and vegetables must begin in the field at the time of harvest and continue throughout their postharvest handling period until they are consumed. This protection is vital, not just to avoid immediate deterioration but to delay the onset of deterioration that would appear later in the distribution channels.

Temperature protection in the field should start with shading of the commodity soon after harvest, followed by rapid handling and cooling to minimize high temperature exposure. This means moving harvested crops to the shade of trees or vines while awaiting transport. If natural shade is not available then portable shading is desirable. At very least, inverting empty containers over the top of stacks of containers, spreading a tarpaulin or other device, can provide some field protection. Figures 2 and 3 show the effects of sun exposure and temperature on three horticultural commodities.

During transport, handling speed is usually the only protection that is provided. Frequent scheduling of commodity transfer from the field to the cooler or packinghouse will minimize the opportunity for deterioration.

Where transport time is extended because of distance or unavoidable delays, the covering of the load may be advantageous. Fruits and vegetables exposed to the sun will warm quickly whether in the field or on top of a loaded truck. Air flow through the load during transport can rapidly bring the commodity to the ambient air temperature. If transport of cool, early-harvested products is delayed until high temperatures are encountered, then the resulting warming will not only speed their deterioration but also increase the cost of subsequent cooling.

Figure 2. Field Temperature of Cherries (Position in Box).

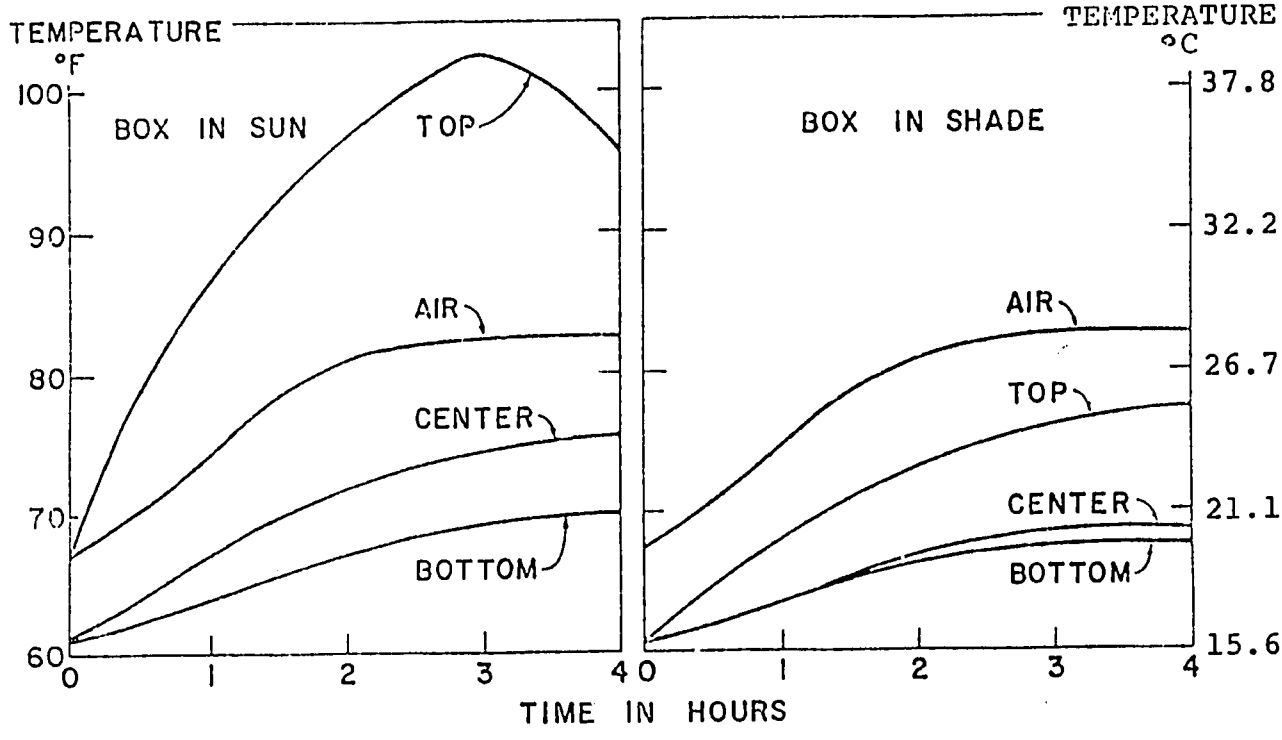
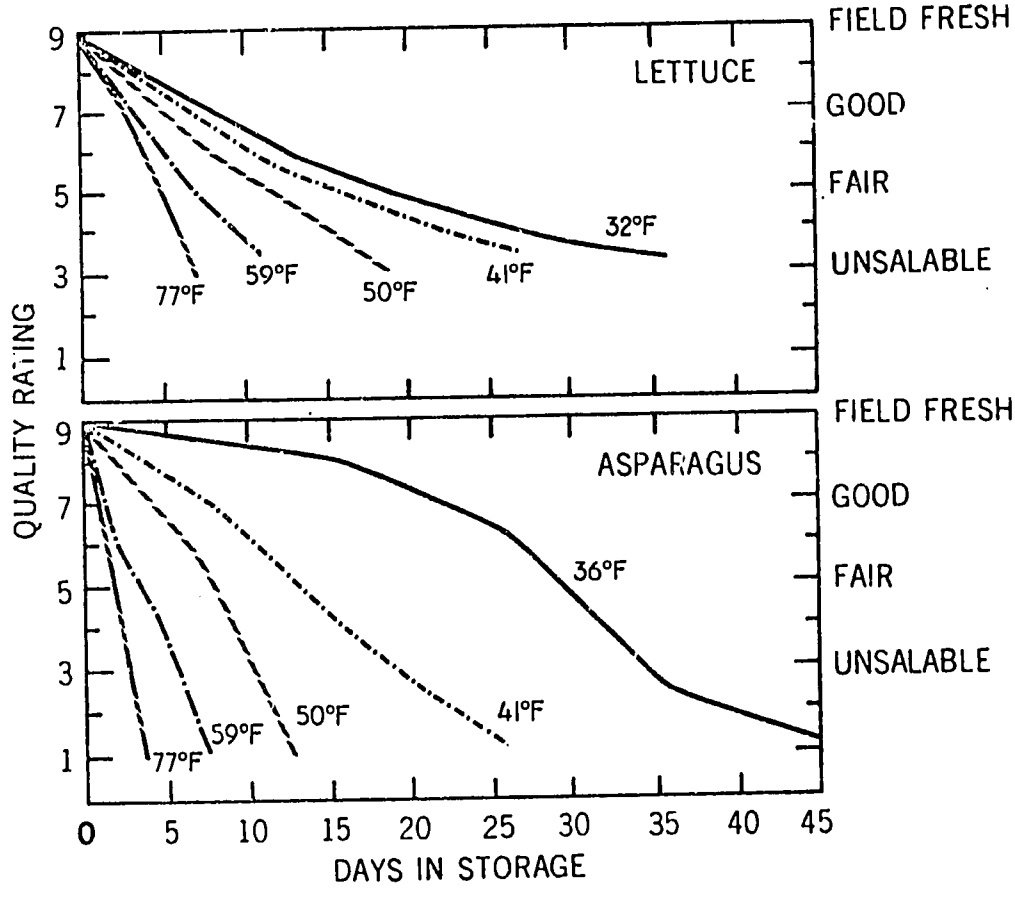


Figure 3. Quality Rating of Asparagus and Untrimmed Lettuce Stored at Five Temperatures for Various Days.



If a tarpaulin is used to cover loads of fruits or vegetables during transport, it should be light color or white and should be kept clean in order to maintain good heat reflectance. If the tarpaulin extends down all sides of the load, it will block air flow through the load and prevent product warming during periods of high ambient air temperatures.

Wetting of the tarpaulin will further reduce warming by providing an evaporative cooling surface. Care must be taken to ensure that a tarpaulin cover does not confine heat within the load and thus accelerate warming of the commodities.

Under difficult transport conditions, with water tolerant products, top ice has been placed over fruits or vegetables in field bins prior to tarping and transport. Of course, ice is not available for this purpose in some countries.

Delayed ripening of fruit by removal of endogenously produced ethylene has been used to enable bananas and plantains to be transported at ambient temperatures instead of under refrigeration. To do this the fruit is sealed in polyethylene bags containing a potassium permangante-impregnated absorbent, which eliminates the ethylene as it is produced.

The horticultural package must accomodate the special temperature requirements of the product. In some cases, provisions for air flow past container surfaces may be sufficient. Often, however, ventilation is needed to facilitate air flow through the container in order to achieve rapid heat removal.

Precooling of Commodity

Precooling is one of the special treatments given to fruits and vegetables before shipment or storage to prevent excessive ripening. Also, to prevent decay or to meet certain quarantine regulations on insects.

Fruits have been called "precooled" when cooled only to 3° to $6^{o}C$, which is still too warm for safe transport. For the more perishable fruits, such as berries, peaches, plums, grapes, early apples or mature pears, this would mean precooling to $5^{o}C$ or lower. For tropical and subtropical fruits, susceptible to chilling injury, cooling to only 10° to $13^{o}C$ would be adequate. Precooling to the desired temperature should be completed within 24 hours and for high perishable fruits like berries, within 2 or 3 hours.

Precooling reduces the amount of refrigeration required during transport and cold storage and also permits heavier loading of the transport vehicle.

Precooling may be done with cold air, cold water (hydrocooling), direct contact with ice, or by evaporation of water from the product under partial vacuum (vacuum cooling). A combination of cooled air and water in the form of a mist is a fairly recent innovation in cooling vegetables. The most common practice for fruits is air precooling. The exception is peaches which are commonly hydrocooled. Vacuum cooling has not found application for fruits because they cool too slowly. The use of crushed ice within the package or on top of the packages loaded in a refrigerated car or truck is not commercial practice for fruits as it is for some vegetables. Regardless of the method of precooling, much of the benefit will be lost if products are not promptly refrigerated afterwards.

RELATIVE HUMIDITY CONTROL

Relative humidity (RH) can influence water loss, decay development, incidence of some physiological disorders, and uniformity of ripening. Condensation of moisture on the commodity (sweating), and not the relative humidity of ambient air, can enhance decay and should be avoided.

RH is never a single immutable factor but can be expected to vary with the parameters listed below.

* Light vs shade
* Morning vs afternoon harvest and/or hauling
* Constant vs changing temperature
* Fast vs slow cooling
* Small vs large containers
* Ventilated vs non-ventilated packages
* Absorbent vs non-absorbent packaging materials

It has been stated that equilibrium RH is never reached in storage; however, this is probably not true in specialized cases such as within a fully loaded, jacketed storage kept at constant temperature.

Many horticultural products suffer deterioration (wilting, shriveling, drying) as a result of water loss during handling and marketing. This water loss occurs because of a water vapor pressure gradient between the product, which is normally at saturation (100% RH), and the surrounding environment which is at a lower relative humidity. During storage it is often desirable

to hold these products at a high relative humidity to minimize water loss. The latter problem, as well as shrinkage, relate more closely to vapor pressure deficit (VPD) than to RH, but at constant temperature, weight loss has a straight line correlation with RH in the upper humidity range (75% RH and over).

Just what degree of weight loss can be tolerated before the product becomes unsalable ranges from as low as 5% for apples and oranges to as high as 37% for green beans. As a general principal, the point at which shriveling is visible is about half of the commercially tolerable weight loss.

Proper relative humidity for fruits is 85-95% and for vegetables is 90-98% except for onions and pumpkins. Onions should be stored at 60-70% RH and pumpkins at 95-100% RH.

During transport and marketing there is usually little environmental humidity control available; thus the package may be designed to provide a partial barrier against movement of water vapor from the product.

Relative humidity control can be achieved by one or more of the following procedures:

a) Addition of moisture (water mist or spray, steam) to the air by use of humidifiers.

b) Regulation of air movement and ventilation in relation to produce load in the storage room.

c) Temperature of refrigeration coils being within 1°C of the air temperature inside the cold storage room.

d) Use of moisture barriers (insulation of storage room, transport walls, and polyethylene liners in containers).

e) Wetting the floor in storage rooms.

f) Use of crushed ice in shipping containers or to display commodities at retail, except those commodities injured by such practice.

g) Sprinkling produce with water during retail marketing (used on leafy vegetables, immature fruit and vegetables, cool-season root vegetables).

With fruits and vegetables, low-temperature and modified-atmosphere storage often provide adequate conservation for those commodities of sufficient value to justify capital and running costs; however, in many situations these technologies are not yet economic, particularly in those that

are the principal focus of this paper. Simple inexpensive alternatives are available for minor storage improvements, but extensive improvements will depend as much on administrative and managerial factors as on technology. Some of the factors are:

1. Choice of planting varieties with good postharvest quality and storage life.
2. Improved packaging, transport and marketing arrangements to move fruits and vegetables rapidly and without damage between production and consumption.
3. Low-cost cooling systems, even relatively small reductions in temperature, offer by far the greatest possibility for extending the life of perishables.

Before closing, I wish to remark that fruits and vegetables, being perishables, undergo quantitative and qualitative losses between harvest and consumption. These losses take place during handling, transport and storage. Data regarding such losses in various Asian and Far East countries are shown below.

Table 4. Fruit and Vegetable Losses by Country

Country	Percent Loss
India	20-30
Indonesia	25
Malaysia	20
Philippines	10-50
Sri Lanka	20-40
Thailand	23-28

Adapted from FAO (1977)

These figures show the urgent need for reducing losses, which aptly has been called the "hidden harvest."

BIBLIOGRAPHY

ASHRAE Handbook, 1982, Applications, Chapter 31, 32 and 33. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta, GA.

Bourne, M.C., 1977. Post Harvest Food Losses: The Neglected Dimension in Increasing the World Food Supply. Cornell International Agricultural Mimeograph 53. Cornell University, Ithaca, NY.

Finney, E.E., Jr. and Hanson, A.A., Eds., Handbook of Transportation and Marketing in Agriculture. Vol. 1: Food Commodities. CRC Press, Inc., Boca Raton, FL.

Food and Agriculture Organization, 1977. "1976 FAO Production Yearbook," Vol. 30: FAO of the United Nations, Rome, Italy.

Grierson, W. and Wardowski, W.F., 1978. Relative Humidity Effects on the Postharvest Life of Fruits and Vegetables. HortScience 13(5): 570-574.

Jiménez, M.A., 1983. Appropriate Technology for the Postharvest Handling of Agricultural Products in Latin America. GTS Report No. PIP/Panama/Jan. 83/No. 1. Postharvest Institute for Perishables. University of Idaho, Moscow, Idaho. (In Spanish).

Kader, A.A. 1980. Nutritional Quality of Fresh Fruits and Vegetables in Relation to Harvesting and Postharvest Handling Procedures, Am. Diet. Assoc., 63rd Am. Meet. Mimeo (presented at Oct. meeting).

Lutz, J.M., and Hardenburg, R.E. 1977. The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. U.S. Depart. Agr. Handbook 66 (rev.). U.S.G.P.O., Washington, D.C.

National Research Council, Commission of International Relations, Board on Science and Technology for International Development. 1981. (2nd Printing), Postharvest Food Losses in Developing Countries. National Academy of Sciences, Washington, D.C.

Ryall, A.L., and Lipton, W.J. 1979. Handling, Transportation and Storage of Fruits and Vegetables. 2nd Edition. Vol. 2: Fruits and Tree Nuts. AVI Publishing Co., Westport, CT.

Svenson, B. 1983. Linderman's Unique Wet Pressure System. Western Grower and Shipper. Feb. Issue, 20-30.

B. FACTORS AFFECTING MARKET QUALITY OF HORTICULTURAL PRODUCE

The system for marketing and distributing agricultural products in every country is large, complex and important. There are several characteristics of agricultural products that make their marketing complicated and the attainment of a good marketing system difficult.

First, in most countries farm products are produced in small quantities on widely scattered farms.

Second, every miscalculation producers make in estimating their market potential will lead to price instability.

Third, most horticultural commodities are produced seasonally, while consumers must be supplied with food all year round.

Fourth, many agricultural products are perishable, which adds to the expense of marketing.

Fifth, individual producers of horticultural crops have limited bargaining strength since they are handicapped by seasonal supplies, perishability of products and other prerequisites of the marketing system.

Sixth, agricultural commodities are characterized by the remoteness of their producers from the ultimate consumers.

Last, the quality of fruits and vegetables is another important attribute.

I have been assigned the task of discussing the factors that affect market quality of horticultural products. I would like to define first the terms quality and quality control.

* Quality means inherent or intrinsic excellence of character or superiority of kind.
* Quality control signifies an aggregate of functions designed to insure adequate quality.

Quality in fruits, as in vegetable products, is that combination of characteristics which makes them desirable to the buyer or user. Horticultural commodities are ordinarily chosen by appearance because other methods for determining quality are rarely available to the casual purchaser. To the vendor of produce, whether at the field, the wholesale display, or in the retail store, such factors as external appearance and freedom from defects are of compelling importance.

The term quality may be used in different ways as shown by the expressions: consumer quality, nutritional quality, nutritional value, while the keeping quality refers to the time that the commodity may be kept without deterioration of quality.

Price

Pricing is the determination of value in terms of money. How to select the best value for the money paid is a difficult decision to make. However, let's keep in mind that good quality and low price do not go hand-in-hand. Price is based very often on size and appearance, which may not reflect either eating quality or keeping quality. Prices may vary from hour to hour or day to day, depending on demand and supply.

Quality Control

Losses of produce, both by direct destruction and by quality deterioration, continue to be high in the marketing of fresh commodities. This situation can be improved by training programs for both wholesalers and retailers so that they can recognize the relation between market quality and losses and thus reduce the latter.

Quality control involves two functions. The first is selection of the produce for the particular market, taking into consideration shipping conditions, considering grade standards and minimum market quality, with maturity always being a major factor. The second is quality maintenance. This requires effective use of available procedures to insure that quality is not impaired throughout the marketing chain.

Maturity

An understanding of maturity is essential for the successful distribution of fruits and vegetables. It is important to the shipper as it affects many marketing decisions, and is similarly important to the wholesaler and retailer.

Maturity indices and maturity standards are needed. To be reliable, they must be consistent and practical. To be effective, they must be readily understood and uniformly applied. Much effort has been devoted to these ends by scientists involved in horticultural quality research and by those responsible for commodity standardization and inspection; however, more research is still needed.

Careful Handling

Another important factor that affects market quality is careful handling and appropriate packaging to keep mechanical damage to a low level. Mechanical injury causes more rapid respiration, and this in turn accelerates ripening which increases decay.

Temperature

All produce should be protected from heating after harvest and brought to the packinghouse without delay. At this point, maturity as well as other external characteristics are assessed to determine suitable market outlets.

Control of temperature of the produce is the most important factor to retard deterioration. It is essential, therefore, to measure temperature of the produce at key points in the packinghouse and throughout the marketing channels. It is also necessary to keep adequate records of temperatures and times, not only to know what is happening but why it is happening.

As shown in Figure 1, lowering the temperature is the most direct and the simplest way to retard respiration, which in turn delays ripening and aging of horticultural products.

The adverse effect of delay before cooling is greatest for very perishable commodities such as Shasta strawberries. This is illustrated in Figure 2.

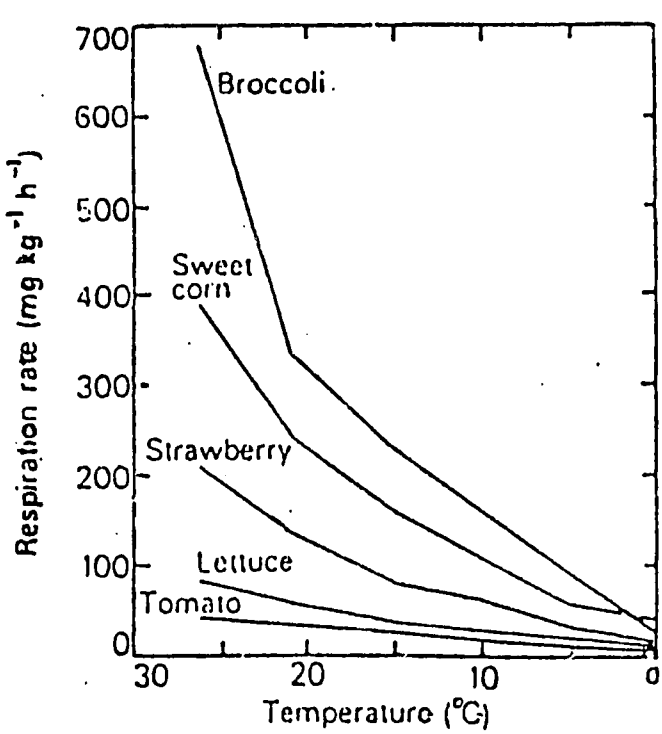


Fig. 1. Effects of Reduction in Temperature on Rate of Respiration

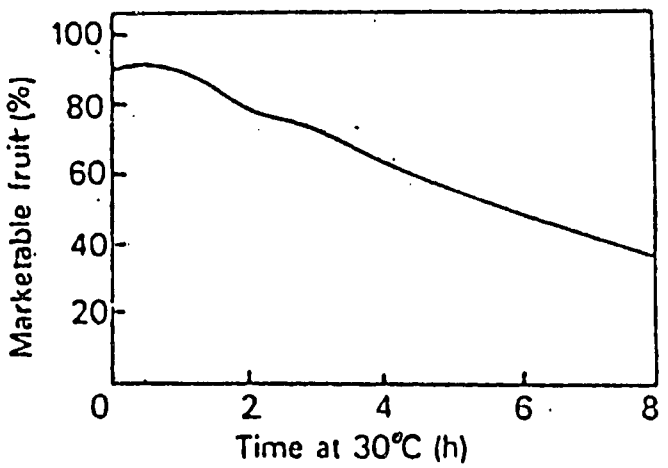


Fig. 2. Effect of delay before cooling on quality of Shasta strawberry. (After Mitchell *et al* 1972)

Temperature also has a marked effect on the depletion of sucrose from sweet corn as illustrated in Figure 3. This also happens with green peas.

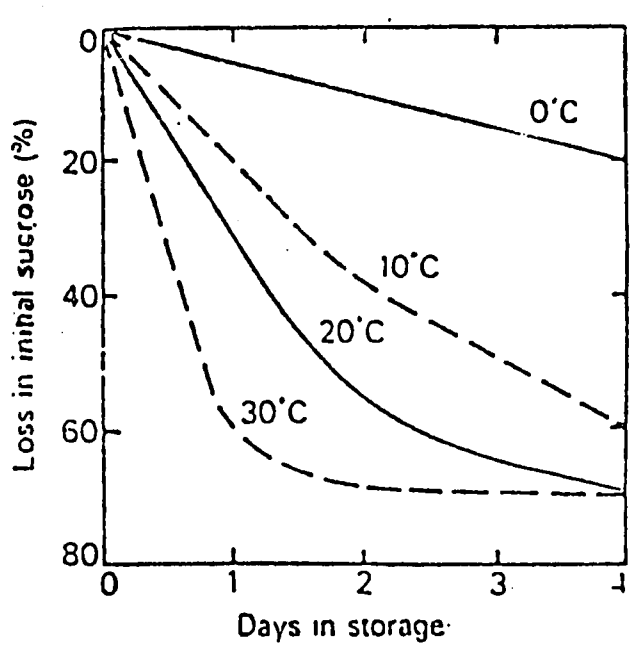


Fig. 3. Depletion of sucrose in sweet corn stored at four temperatures. (Adapted from Appleman and Arthur 1919)

Rot-producing pathogens grow best and more rapidly at temperatures close to 25°C, but only slowly or not at all at low temperatures. The common green mold that attacks oranges will produce a rot in 3 days at 25°C, but at 5°C it takes about 25 days, and at 0°C it requires more than 60 days. This is presented graphically in Figure 4.

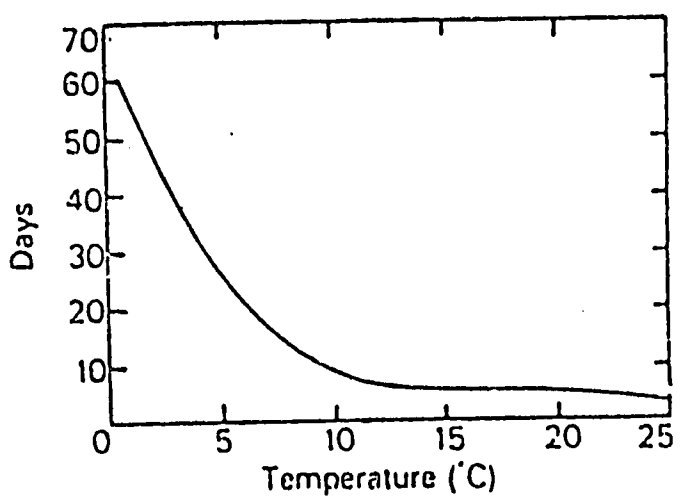


Fig. 4. Effect of temperature on the development of green mould in oranges.

The ripening of certain fruits such as bananas, tomatoes and certain pears is very sensitive to temperature. Bananas, for instance, will ripen well only within the very narrow range from 18°C to 23°C, while pears and tomatoes ripen poorly above 30°C and below 15°C.

Transpiration (Water Loss)

A major factor that affects quality after harvest is water loss and consequent wilting. Leafy vegetables and beans wilt much faster than fruits, especially round fruits. Water loss causes not only lack of freshness, but also loss of saleable weight which significantly reduces profit.

Temperature Management

The most readily available method for controlling the postharvest environment is proper temperature management. In warm weather, cooling of very perishable items is highly recommended and most fruits and vegetables benefit from it and will sell better. Whether special cooling is necessary

will depend on the kind of commodity, as well as the ambient temperatures and the duration of transport and marketing.

Forced air cooling is generally best for perishable commodities, particularly if the air is nearly saturated with water vapor. This is almost essential to prevent wilting of produce with a high surface-volume ratio which is prone to lose moisture rapidly. To this group belongs spinach, lettuce, broccoli, green beans and strawberries.

Cold storage rooms are an essential part of any produce handling facility so that commodities can be promptly cooled and held at optimum temperatures before marketing. This also provides a strategic tool for the holding of produce for short-term periods of oversupply or to take advantage of anticipated undersupply.

It is commonly believed that precooling without continued refrigerated storage is worse than no cooling at all. This is not necessarily so. Many tests have demonstrated that the amount of deterioration suffered by produce is a function of total time in storage x temperature, which can also be referred to as total degrees x days.

Moisture condensation on the surface of produce transferred from a cold storage room or transport vehicle into a warm, humid environment is difficult to remove. This problem is commonly known as "sweating." Its continued presence provides ideal conditions for the development of decay once the produce has warmed up. If "sweating" is likely to occur, the consignment should be open-stacked to accelerate warming, which facilitates evaporation thus reducing the amount of condensation. Unless warming is necessary to stop "sweating" or for ripening purposes, precooled produce should be kept cool.

Short Cold Storage

For short distance shipments, closed storage under cover may suffice. For intermediate journeys, closed storage in an insulated vehicle is often satisfactory, but for long distance shipments, proper storage in a vehicle both insulated and refrigerated is necessary.

Most produce is usually sold rapidly in the wholesale market, but if not, it should be held under refrigeration. Of course, precooled, very perishable, high value items should be kept refrigerated at all times. As the benefits of refrigeration and continued temperature management are being more widely appreciated, more and more wholesalers are installing cold storage rooms.

For the full benefit to be realized, quality maintenance by temperature control must be continued through retailing. The ideal facility for retailing is a cool store, where refrigerated produce displays are kept stocked with the most perishable items, but excluding the very chilling-sensitive kinds such as bananas.

To decrease risk of chilling injury, to reduce "sweating," and to minimize weight loss, the cold room should be kept at $5^{o}C$ and 95% relative humidity. For this to be possible, both the cold room and its refrigeration equipment must be correctly designed and efficiently run at all times.

Other precautions required to improve quality maintenance at the retail level are:

* Avoid overloading the cold room.
* Store the produce leaving air paths around, under and through the stacks.
* Turn over the stock rapidly and do not hold very perishable produce more than 3 to 4 days.

Long Cold Storage

Long cold storage is an essential part of the marketing of apples, pears and other seasonal crops. Initial cooling must be rapid, and required temperatures, as well as gas concentrations on controlled-atmosphere (CA) storage, must be kept as constant as possible.

After the initial cooling period, variations in air temperatures in different places in the stack should not exceed $1^{o}C$, above or below the required temperature. Uniform conditions can only be achieved if the cold storage room has been properly designed. This means:

* Adequate insulation
* Efficient heat barrier, especially on the warm side of the room
* Sufficient cooling surface in the refrigerating equipment
* Adequate air circulation
* Efficient air distribution

The common fault of over-storage must be avoided as recommended for short cold storage. Fruits that are kept too long in cold storage reach the retail market in poor condition.

Sanitation Conditions

Maintenance of sanitary conditions within storage rooms is an essential of "good housekeeping." After serval months' operation of a storage room, even at -0.5^{o}C, molds grow on the surfaces of packages and on the walls and ceilings, especially when kept under high relative humidity conditions. To correct this problem, storage warehouses should have a thorough cleaning at least once a year. Good air circulation is also of considerable value in minimizing growth of surface molds.

A complete storage cleanup should be done when rooms are empty. The floors should be cleaned of all debris and scrubbed. A practical way to clean the ceiling and walls is to apply whitewash as a spray. If floors and walls become moldy, they can be scrubbed with a cleaner containing sodium hypochlorite or trisodium phosphate, then rinsed and the room aired.

Field boxes and equipment can be cleaned with 0.25 percent calcium hypochlorite solutions or by 2 minutes exposure to superheated steam.

The hazard of infecting horticultural products often occurs during grading and packing, before or after storage. This is especially grave if decay is present in the commodity, and if condensation moisture occurs on the packed product. Sanitary precautions should be taken in handling decayed material. Rotting fruits and vegetables should be handled carefully to avoid spreading spores, and once removed from the container, rotting produce should be disposed of promptly.

Air Purification

Air purification is a recommended practice in storage rooms where odors or volatiles may contribute to off flavors and also hasten deterioration. Usually air purification involves the use of trays or canisters containing activated coconut shell carbon. Its widest application is in fruit storage, particularly controlled-atmosphere (CA) storage, where it helps to eliminate undesirable odors.

Mixed Commodities

At times, it might be necessary to store different products together. This may or may not be safe. Deciduous fruits can generally be stored together if they have the same temperature requirements, but with some products there is a cross-transfer of odors. Also volatiles such as ethylene, which are emitted by several commodities, may be harmful to others.

Combinations that should be avoided in storage rooms are apples or pears with celery, cabbage, carrots, potatoes, or onions; celery with onions or carrots; citrus fruits with any of the strongly scented vegetables. It is recommended that onions, nuts, citrus fruits and potatoes be stored separately.

Lettuce and carrots are damaged when stored with apples, pears and some other fruits and vegetables because of the ethylene given off from the latter products as a natural emanation. Green mold of citrus and probable other decay organisms also produce ethylene. Products such as cucumbers, peppers and acorn squash, in which retention of green color is desirable, should be stored at 6.5^{o}C to 10°C and not kept with apples, pears, tomatoes or other ethylene-producing crops.

Losses due to pathological damage are minimized by care in harvesting and appropriate storage treatments and conditions.

BIBLIOGRAPHY

Appleman, C.O., and Arthur, J.M. 1919. Carbohydrate Metabolism in Sweet Corn. J. Agric. Res. 17, 137-52.

ASHRAE. 1982. Applications, Chapters 31,32 and 33. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA.

Bautista, O.K. 1982. Postharvest Handling of Tropical Fruits and Vegetables in ASEAN. International Food Congress, Singapore, May 16-21.

Finney, E.E., Jr. and Hanson, A.A. Eds. 1981. Handbook of Transportation and Marketing in Agriculture. Vol. 1: Food Commodities, CRC Press, Inc., Boca Raton, FL.

Hall, E.G. 1980. Market Quality and Condition - A Cold Appraisal. Proc. Strathleven Centenary Symp. on Refrig. (6p.).

Kayan, C.F., and Francis, J.G. 1947. Controlled Air Distribution is Secret of Good Apple. Refrig. Engin. 54 (5) 444-48.

Lutz, J.M., and Hardenburg, R.E. 1977. The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. U.S.D.A. Handbook 66 (rev.) U.S. Govern. Print. Off., Washington, D.C.

Mitchell, F.G., Guillou, R., and Parsons, R.A. 1972. Commercial Cooling of Fruits and Vegetables. Univ. of Calif. Manual No. 43.

Morrison, W.R. 1976. Keynote Address. CENTO Seminar on the Marketing of Agric. Products (6p.).

Ryall, A.L., and Pentzer, W.T. 1982. Handling, Transportation and Storage of Fruits and Vegetables. 2nd Ed., Vol. 2: Fruits and Tree Nuts. AVI Publishing Co., Westport, CT.