



From the Farm to Your Table

A Consumer's Guide to Fresh Fruits and Vegetables

James Thompson & Adel Kader



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Contents

Introduction	1
What Does Quality Mean?	2
Quality Begins on the Farm	3
Growing Conditions.....	3
Growing Practices.....	3
Maturity at Harvest.....	4
Produce Handling.....	5
From Grower to the Market	6
Long-Term Storage.....	10
Transport to Market	10
How To Select Good-Quality Produce at the Market.....	11
Home Storage.....	14
Food Safety at Home	15

Introduction

Fruits and vegetables are a vital part of our diet. They provide vitamins, minerals, dietary fiber, and antioxidants to keep us healthy. There is truth to the old saying, “An apple a day keeps the doctor away.” The new version, however, is “Five fruits and vegetables a day keeps the doctor away,” with the added recommendation to eat produce of various colors in order to get a full range of antioxidants and phytonutrients.

There is more to fruit and vegetable quality than meets the eye. Good appearance does not necessarily indicate good nutritional quality and it certainly does not guarantee good taste. The goal of this publication is to describe how various factors affect quality. One factor, for example, is the plant cultivar (variety) which the farmer chooses to grow. Other factors affecting fruit and vegetable quality include growing location, growing methods, handling procedures, and marketing systems. This publication also explains how to select good-quality produce at the store and how to handle it at home to maintain its quality and safety.



What Does Quality Mean?

Produce quality means different things to different people. Farmers want their produce to have good appearance and few visual defects. They want their crops to yield well, resist disease, harvest easily, and ship with little quality loss. To wholesale marketers and distributors, appearance quality is most important. They also want produce to maintain firmness and have a long postharvest life. Consumers value fruits and vegetables that look good, have a firm texture, and offer good flavor and nutritive value. They buy initially on the basis of appearance and feel. But repeat purchases are made if the produce tastes good.

Table 1. Influence of sugar and acid levels on taste

	Low sugars	High sugars
Low acids	insipid, tasteless	sweet
Moderate to high acids	sour, tart	best flavor

Produce flavor is influenced by levels of sugars, organic acids, aroma volatiles, and astringent phenolic compounds. Sugar and acid levels have the greatest effect on taste (table 1). Much remains unknown about the specific levels of flavor compounds needed for individual fruits and vegetables to taste good. Consumers often will pay a higher price for produce with good flavor and there is a growing number of stores offering high-quality produce to serve this clientele. For the same reason, some consumers buy their produce at farmers' markets, roadside stands, and by subscription with a local farmer. Researchers are developing rapid, nondestructive methods to measure taste-affecting compounds. In the future, machines may be able to sort out poor-tasting produce.

The postharvest life of fruits and vegetables, measured by flavor and nutritional quality, is only 65 to 75 percent as long as their appearance life. This is due to the loss of sugars, acids, and aroma volatiles, and the development of off-flavors. These losses occur before produce looks old. Because some quality loss occurs during transport and storage before produce reaches the home refrigerator, fruits and vegetables should usually not be stored at home for more than one week. There are a few exceptions like onions, garlic, and potatoes that have long postharvest lives and can be stored for many weeks.

Farmer inspecting avocados. *Photo: Jack Kelly Clark.*



Quality Begins on the Farm

Plant Cultivar

Consumers commonly buy apples according to their awareness of the differences between cultivars. (Plant scientists use the word *cultivar*, derived from *cultivated variety*, to describe different types of the same plant species.) Apples with names like Fuji, Jonagold, and Golden Delicious look and taste different from one another. Most other produce items are also grown from a number of plant cultivars, although they might not look different on the outside. For example, farmers grow over 400 cultivars of peaches, nectarines, and plums, yet few people know the names of the individual cultivars. While differences in external appearance among cultivars may be subtle, they may vary noticeably in taste and nutritional quality.

The range of plant cultivars come from breeders who have released cultivars with unique characteristics. For example, there are carrots and tomatoes with much higher levels of carotenoids and vitamin A, sweet corn that is sweeter longer after harvest, and cantaloupes with higher sugar content and firmer flesh. Responding to consumer demand, some marketers offer high-quality cultivars with a guarantee of good flavor or nutrition.

Growing Conditions

Climate factors, especially temperature and light intensity, can strongly influence the composition of fruits and vegetables. This means that the growing location, as well as the season in which plants are grown, influence flavor and nutritional quality. Generally, lower light intensity

reduces ascorbic acid levels. Temperature, on the other hand, has mixed effects on produce nutrition. High temperatures increase water use by the leaves and may cause more nutrients to flow to fruit. It also can limit sugar accumulation because fruit use extra sugar to survive in high-temperature conditions. Freezing temperatures damage produce and reduce quality and marketability. The amount of rainfall is another influential factor. High rainfall increases water supply to the plant, which may reduce nutrient concentration and increase susceptibility to bruising and mechanical damage. Rainfall during flowering and fruit development usually increases plant disease problems.

Growing Practices

Soil type, the rootstock used for fruit trees, mulching, irrigation, and fertilization all influence the water and

Supermarket display with several cultivars of apples. Photo: James Thompson.



nutrient supply to the plant, which can affect the flavor and nutritional quality. Growing practices can also have a significant influence on mineral content. High calcium levels in fruits tend to increase postharvest life because they delay ripening, increase firmness, and reduce the incidence of fruit disorders and decay. High nitrogen content has the opposite effect and shortens postharvest life because it increases susceptibility to mechanical damage, physiological disorders, and decay. Overall, fertilizers have less effect on

vitamin content than do plant cultivar choice and climatic conditions.

Severe water stress causes problems like sunburn of fruits, irregular ripening of pears, tough and leathery texture in peaches, and incomplete kernel development in tree nuts. Moderate water stress reduces fruit size and increases levels of soluble solids, acidity, and ascorbic acid. Excess water supply to plants causes cracking in fruits like cherries, prunes, and tomatoes, increases susceptibility to physical damage, reduced firmness, delayed maturity, and reduced sweetness.

Certain growing practices, like improper pruning and inadequate fruit thinning, increase crop load on trees, causing smaller fruit size, poor flavor, and reduced nutritional quality. Pesticides and growth regulators do not directly influence nutrient levels but may indirectly increase them if they delay maturity or decrease them if they accelerate fruit maturity.

Maturity at Harvest

Best eating quality for most vegetables is reached before full maturity. Delayed harvest results in lower quality and faster deterioration after picking for root vegetables like carrots and radish; leafy and flower vegetables like lettuce, spinach, artichoke, and broccoli; and immature fruits like cucumber, sweet corn, green bean, and pea.

For fruits, maturity at harvest is the most important factor determining storage life and final quality. Immature fruits are more subject to shriveling and mechanical damage and have poor quality when they ripen. Overripe fruits quickly become soft and mealy with bland flavor after harvest. Fruits not

A field of strawberries for the fresh market. *Photo: Jack Kelly Clark.*



picked at optimum maturity are also susceptible to physiological disorders and have a shorter storage life than those picked at optimum maturity.

Most fruits and mature fruit vegetables, like melons and tomatoes, reach best eating quality when allowed to ripen on the plant. But often fruits are picked before best eating quality so they can withstand harvest, handling, and long distance shipping. Commercial standards for maturity are a compromise between characteristics that ensure the best eating quality and those that provide the needed flexibility in marketing.

A few fruits reach best eating quality after picking. Apple, apricot, avocado, banana, cantaloupe, honeydew melons, kiwifruit, mango, nectarine, peach, pear, and plum all develop better flavor and texture if allowed to ripen at room temperature. At home these items should be stored at room temperature until they are ripe and then refrigerated. Some of these fruits are exposed to low levels of ethylene, a naturally occurring plant-ripening hormone, to speed ripening and make the fruit ripen more evenly.

Produce Handling

Rough handling, poorly designed packinghouse equipment, overfilling boxes, and squeezing produce on retail display are all causes of bruises and cuts. This damage causes unappealing surface injuries and brown flesh, accelerates water loss, provides entry points for decay, and speeds nutrient loss, particularly vitamin C.

Shoulder bruising of Bing cherries caused by pickers pulling on the fruit to remove it from the tree instead of removing the fruit by grasping its stem.

Photo: Jack Kelly Clark.



Wounding of peaches during harvest and handling. *Photo: Don Edwards.*



Banana ripening room. *Photo: Mike Poe.*

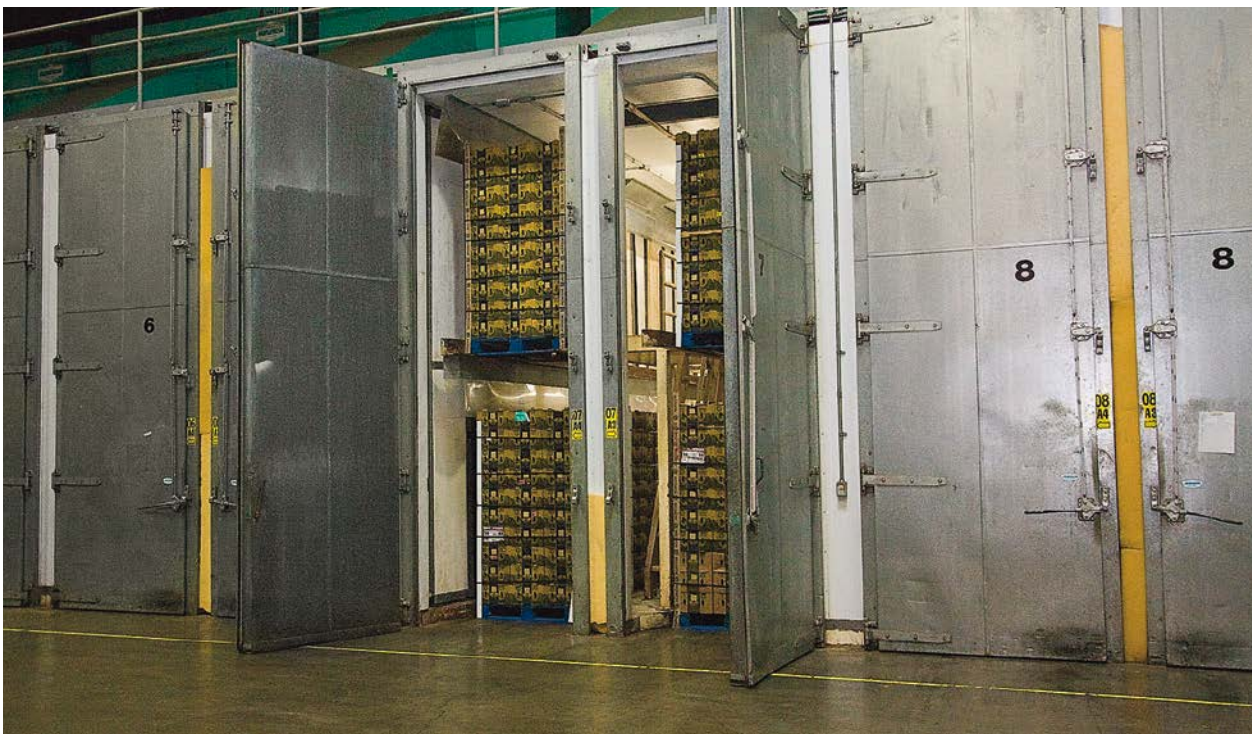


Figure 1. Handling steps between production area and retail market for produce packed in a packing house.

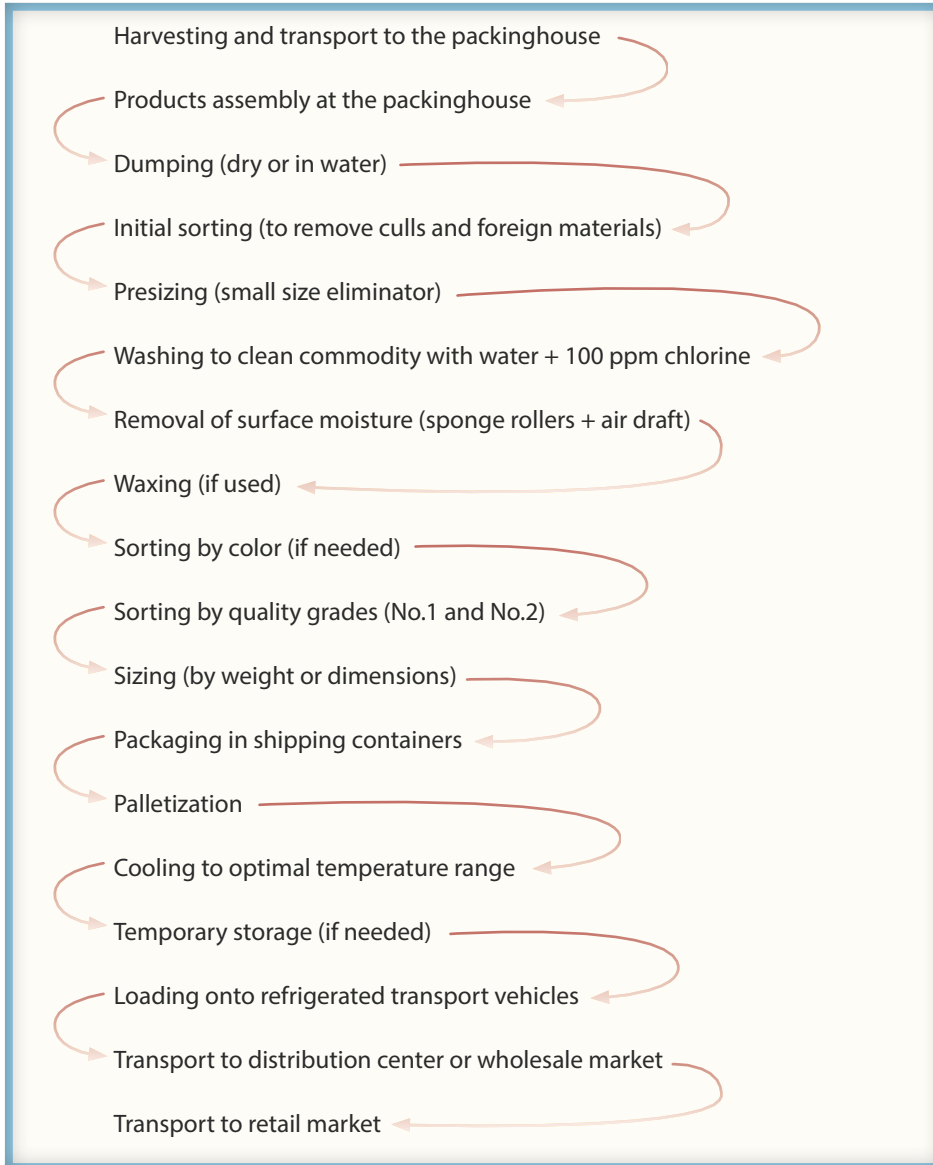
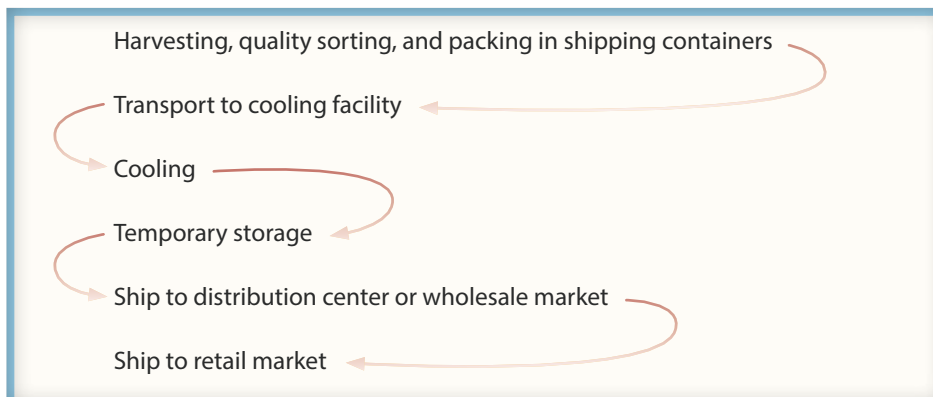


Figure 2. Handling steps between production area and retail market for produce packed in the field.



From Grower to the Market

Getting tree fruits and fruit-type vegetables (like tomatoes) from the production area to retail markets involves many steps (fig. 1). Handling produce like strawberries, lettuce, and broccoli is much simpler because the picker does all of the sorting and packing in the field (fig. 2).

Nearly all produce items must be quickly cooled after picking to slow quality loss. Temperature management is the most important factor that controls product quality; it is more important than choice of cultivar or growing conditions. Produce like strawberries and raspberries have a high level of biological activity, causing them to quickly lose taste and nutrients even at room temperature (fig. 3). This kind of produce must be cooled within two hours after picking for longest possible life. Sweet corn, including the new super-sweet cultivars, lose sugar very rapidly so cooling must begin within four hours after harvest. Other products, like citrus fruits, are hardier and can wait almost 24 hours before cooling begins. A few items (like tomatoes, pears, and avocados) need to ripen after harvest, and holding them for short periods near room temperature actually improves their eating quality.

Forcing refrigerated air past produce is the most common method of initial cooling. Forced-air cooling is done in a refrigerated storage facility with the aid of a fan system to push or pull air through the holes in the sidewalls of boxes. The warmed air is re-cooled and used again. Cold water is also used for cooling items that can withstand water contact. Cherries, sweet corn, asparagus, leafy greens, and carrots are usually hydro-cooled. It is faster than forced-air

cooling but the water must be treated with a disinfectant, usually chlorine, to prevent spreading plant decay organisms to uninfected produce. A few leafy green vegetables are cooled by placing them in a vacuum chamber. The vacuum causes rapid evaporation of surface moisture, which cools them in about half an hour. Vacuum cooling is common for lettuces. Ice is occasionally added to packed boxes to cool the product. However, it is an expensive cooling method and its use is declining.

Commercial forced-air cooler. *Photo: James Thompson.*



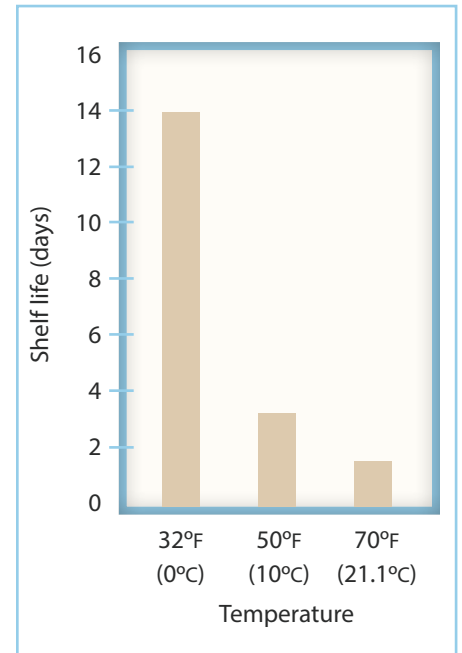
Commercial-scale hydro-cooler. *Photo: Mike Poe.*



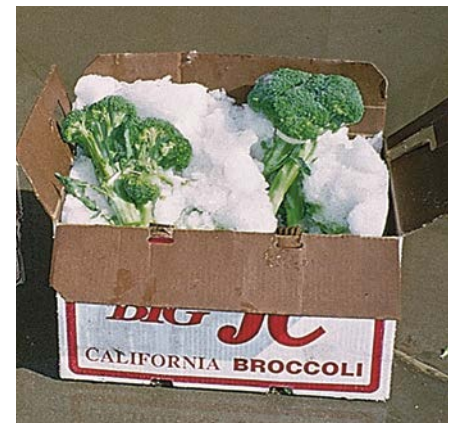
Vacuum cooler for leafy vegetables. *Photo: James Thompson.*



Figure 3. High temperature reduces the shelf life of strawberries.



Box of broccoli filled with crushed ice. *Photo: James Thompson.*



Produce Temperature

Fruits and vegetables are living plant parts even after they are harvested. At picking they are usually near peak quality—highest sugar content, best nutrient level, and optimum eating texture. As time passes following harvest, they lose quality because natural living processes consume their sugars and nutrients, and water escapes from the surface of the product. These processes speed up as temperature increases. For example, table grapes can be stored for about three months when held slightly below 32°F (0°C). But at 50°F (10°C) their life is reduced to 25 percent of maximum and at room temperature it is only 10 percent of maximum. At warm room temperatures their stems will turn brown in a few days. Many fruits and vegetables native to subtropical and tropical parts of the world are best held at temperatures closer to room temperature. For example, bananas, tomatoes, and papayas have longest life at 55° to 65°F (12.8° to 18.3°C). Below this temperature range they lose flavor quickly, do not ripen properly, and are subject to decay. See table 2 for the best conditions for home storage of common fruits and vegetables.

Most fruits and vegetables have best quality if they are eaten quickly after harvest. But remember: the effects of time and temperature on quality are linked. Short distances between the grower and consumer does not mean good quality if produce is not quickly cooled and held at low temperature after harvest.

Packages

Most vegetables and fruits are packaged before cooling. Packaging makes it easier to handle the product and protects it from mechanical damage. The package is usually made from corrugated fiberboard. Returnable plastic containers are popular with some retail markets. Containers are built with holes to speed produce cooling. Some items like berries, grapes, mushrooms, and cherry tomatoes may be packed in a display-ready container or plastic bag to slow moisture loss and protect them from damage while on display. The extra cost of the packaging is more than paid for by the reduction in spoiled or damaged product.

Corrugated fiberboard box for produce. *Photo: Mike Poe.*



Returnable plastic container. *Photo: Mike Poe.*



Clamshell package or bag. *Photo: Mike Poe.*



Table 2. How to store fresh fruits and vegetables at home

Where to store	Fruits and melons		Vegetables	
store in refrigerator	apples		artichokes	green onions
	apricots		asparagus	herbs (not basil)
	Asian pears		green beans	leafy greens
	blackberries		lima beans	leeks
	blueberries		beets	lettuce
	cherries		Belgian endive	mushrooms
	cut fruits		broccoli	peas
	figs		Brussels sprouts	radishes
	grapes		cabbage	spinach
	raspberries		carrots	sprouts
	strawberries		cauliflower	summer squashes
			celery	sweet corn
			cut vegetables	
ripen on counter, then store in refrigerator	avocados	pears		
	kiwifruit	plums		
	nectarines	plumcots		
	peaches			
store on counter at room temperature	apples <7 days	melons	basil (in water)	peppers [†]
	bananas	oranges	cucumbers [†]	potatoes*
	grapefruit	papayas	dry onions*	pumpkins
	lemons	persimmons	eggplant [†]	sweet potatoes
	limes	pineapple	garlic*	tomatoes
	mandarins	plantain	ginger	winter squashes
	mangoes	pomegranates	jicama	
		watermelons		

Notes:

* Store in a well-ventilated area in the pantry. Protect potatoes from light to avoid greening.

[†] Can be kept in the refrigerator for 1 to 3 days if used soon after removal from refrigerator.

Moisture Loss

Shriveling, an obvious indicator of poor product handling is caused by excessive water loss. Wilting-sensitive items like spinach and table grapes appear shriveled with only 3 to 4 percent weight loss. Water loss begins as soon as the product is picked in the field and continues during

storage and marketing. Keeping produce at its lowest safe temperature and at 85 to 95 percent relative humidity is the best way to slow water loss. Bags or plastic containers also slow moisture loss, but packaging has limited value if produce is not kept cold.

Long-Term Storage

A few items are available to consumers for many months a year because they can be stored after harvest and still maintain good eating quality. Many apple cultivars, some pears, table grapes, carrots, potatoes, onions, cabbage, and sweet potatoes are commonly stored so they are available in the market long after harvest ends. Special-built refrigerated storages keep the product at their optimum storage temperature and at a high humidity to slow quality loss. The storages for apples, pears, and cabbage are sometimes built gas-tight so that oxygen levels can be reduced and carbon dioxide levels increased to even further slow the loss of product quality. Importing off-season fruits and vegetables from the southern hemisphere is reducing the need for long-term storage in North America. Long-distance

marine transport to North America is an added cost, but it offsets the cost of refrigerated storage. Compared with stored fruit, southern hemisphere fruit has the potential for better quality because it is harvested closer to the time of consumption. But this potential is reached only if it is grown, harvested, and handled for optimum quality.

Transport to Market

Most produce grown in North America is shipped to market by truck. Special-built, insulated semi-trailers are fitted with refrigeration systems and provide the link between cold storage near the production area and the refrigerated storage at wholesale. The trucks usually hold several items, and the load must be carefully planned to insure that the items are compatible. Produce held at temperatures near freezing, like most leafy green vegetables, cannot be shipped with tropical fruits that must be held near room temperature. Some fruits and melons, like cantaloupe and some cultivars of apples, naturally emit ethylene gas and must be separated from items like green vegetables that are damaged by the gas. Other items, like garlic, emit odors and cannot be shipped with produce that absorbs odors.

Imported produce like bananas, mangoes, pineapples, and wintertime grapes arrive at North American ports in refrigerated ships or marine containers. They provide very good temperature control and they are a very energy-efficient means of transport. Airfreight is used for some imported produce, but it is quite expensive and energy intensive. It is used mostly for high-valued items. Airplane cargo holds are rarely kept at best temperatures for perishable produce, although they offer containers cooled with dry ice, at an extra cost.

Refrigerated storage facility. Photo: James Thompson.



How To Select Good-Quality Produce at the Market

Considering all the factors that influence produce quality, it is no wonder fruits and vegetables do not have consistent quality at the market. Faced with the potential of variable quality, what can a consumer do to select quality produce at the store?

Some markets have consistently better produce than others. You learn the reputation of stores mainly by experience. Even before you know a store's reputation, you can recognize the signs of a good produce section. Stores with good-quality fruits and vegetables sell them quickly and they do not stay on display long. This means there is little wilted produce. Leafy green vegetables are crisp, grapes have green, not brown, stems, and berries are free of decay fuzz on the fruit. Temperature is key to quality, and good produce sections have plenty of refrigerated displays. Farmers' markets rarely have refrigeration but quality loss is slowed by shaded displays. Markets with good produce are clean.

At the store, select produce that appears fresh. Do not select items that are shriveled, wilted, or show signs of decay. Damage caused by weather during growing or damage to the peel from surface-feeding insects, does not have nearly as much impact on quality as recently inflicted damage like stem punctures from neighboring fruit, soft sunken areas, or torn leaves. Fruits and melons with characteristic aroma often taste good. A bag of potatoes with a strong earthy smell has tubers with bacterial rot, and head lettuce with a bitter smell has a bitter taste. Details for selecting good produce items are listed in table 3.

Refrigerated highway trucks. *Photo: Mike Poe.*



Healed scar on nectarine looks unsightly but has little effect on fruit quality.

Photo: Don Edwards.



Skin abrasions on bananas are a sign that they were roughly handled and may have bruised flesh. *Photo: Don Edwards.*



Table 3. How to select good-quality fresh fruits and vegetables

Item	What to look for
apple	firm, well colored (red cultivars: apples with less green background color usually have better flavor); avoid shriveled and soft apples and those with defects or decay
asparagus	compact tips, green color over most of the spears, no bruised or water-soaked or decayed areas; large-diameter spears are more tender than small-diameter spears
avocado	slightly soft avocados for immediate use; skin color of Hass avocados changes from green to black as they ripen while other cultivars remain green
banana	more round than angular in cross section (round are more mature), firm, bright color; avoid dull-colored, gray-discolored, or bruised bananas
beans, snap	firm, tender pods (immature seeds), bright color for the cultivar; avoid shriveled, discolored, and decayed pods
broccoli	compact, dark green heads (no open yellow florets), no water-soaked areas or decay
cabbage	firm heads that are heavy for their size, good color (green or purple) for the cultivar, no wilted, discolored, or decayed leaves
cantaloupe	no stem attached, thick and corky netting on the surface, yellowish-buff color, pleasant aroma
cauliflower	white to creamy-white color, compact and clean surface, nonwilted and green jacket leaves
celery	fresh (not wilted or discolored), crispy, green stalks
grape	well colored for the cultivar, firm berries with green stems; avoid bunches with berries that are soft, shriveled, or have bleached areas around the stem
grapefruit	firm and heavy for its size (these are juicy), bright-colored with smooth skin, not shriveled, discolored, pitted, or decayed
honeydew melon	firm, smooth (waxy) and creamy-white to creamy-yellow skin, slightly soft at the blossom end, pleasant aroma
lettuce	fresh and crisp (not wilted) leaves with bright color of the cultivar (green or red), no discolored or water-soaked or decayed areas

Item	What to look for
mango	bright color for the cultivar (more yellow than green in the background color indicates riper mango); select soft mangoes for immediate use and firm mangoes for use after ripening in a few days; avoid those with gray discoloration, pitting, or black spots
mushroom	closed caps around the stem, white or creamy or light-brown color (depending on the type of mushrooms), no discolored or soft spots
onion	hard or firm with small, dry necks and dry outer scales; no sprouting, bruises, or decay
orange	firm and heavy for its size (juicy), bright and smooth skin, not bruised, shriveled, pitted, or decayed
peach and nectarine	plump and juicy, more yellow than green background color (between the red areas), not shriveled, bruised, or decayed
pineapple	yellowish-green to golden brown shell color, firm and heavy for its size, dark green and nonwilted crown leaves; free from defects and decay
potato	well shaped and colored for the cultivar, smooth, firm; no green areas, sprouting, cuts, bruises, or decay
strawberry	full red color, bright luster, firm flesh; no bruises or decay
sweet corn	fresh (not wilted) and green husks, silk end free from worm injury and decay; plump and nondented kernels
tomato	uniform good color for the cultivar, firm; free from bruises, cracks, and decay
watermelon	full shape for the cultivar, firm, relatively smooth surface, creamy color of the underside (ground spot)

Fruits and melons often vary in quality during their harvest season. Early-season produce is often harvested too soon and is frequently immature. Quality usually improves as the harvest season progresses and price drops. Summer-harvested fruits and vegetables available in the winter are often imported. This may be good for apples and pears because the fruit has been in storage or transport less time than fruit harvested in the summer or fall and held in refrigerated storage. Shorter-lived commodities, like peaches and melons, may have lost quality because of the two to three weeks of transport time, and they may have been harvested at low maturity to withstand the trip to the United States.

Even experts cannot always identify a good piece of produce. Melons are notorious for being difficult to select. The sure way to get good produce is to ask the department manager for a sample to taste. Returning fruits and vegetables to the store if their flavor quality is poor is a great idea. This feedback encourages retailers to pay greater attention to the flavor quality of the products they sell.

Home Storage

The kitchen is the last step in the produce-handling chain. The quality issues that dictate handling methods from the grower to the retail store continue to dictate handling at home. First, produce is perishable and has already lost a significant amount of its life after harvest. As a general rule, do not store produce for more than 7 days in a refrigerator. Produce cannot maintain good quality and flavor unless it is handled correctly, and temperature is the key to slowing quality loss (see table 2). Some items should be stored at room temperature because refrigerator temperatures damage them or prevent them from ripening. For example, when stored in the refrigerator, bananas develop black skin and do not ripen, while sweet potatoes develop off-flavors and do not soften properly when cooked. Watermelons lose flavor if refrigerated for more than 3 days. Other produce items should be ripened on the counter and placed in the refrigerator only after they have softened to eating quality. Bartlett pears turn yellow and develop an appealing aroma on the counter. Avocados, kiwifruit, and peaches taste better if ripened before refrigeration. Many other items should be placed directly in the refrigerator and kept there until eaten. Wilting-sensitive items, like

Some fruits achieve best flavor and texture after ripening at room temperature. *Photo: Mike Poe.*



carrots and leafy vegetables, benefit from storage in perforated plastic bags. Put ethylene-producing fruits (such as apples, peaches, and pears) in a separate drawer away from vegetables.

Food Safety at Home

Prevent cross-contamination with harmful bacteria by keeping fruits and vegetables separated from raw meat, poultry, and seafood in the grocery cart and at home.

Soon after arrival at home, place fresh-cut products in the coolest part of the refrigerator and store intact fruits and vegetables according to table 2. Wash all fruits and vegetables and unpackaged prepared salad mixes just before preparation for eating under running water and scrub them with clean hands or a clean scrub brush (for products that are not damaged by such treatment). Do not soak produce in water because it increases chances of cross-contamination with harmful bacteria. Dry the washed produce with clean disposable paper towels. Cut out bruised and discolored areas before eating. It is best to use a clean cutting board for fruits and vegetables, one that is not used for cutting poultry, meat, and seafood. Before and after handling produce, make sure the work area and utensils are clean and wash your hands with hot, soapy water. It is not necessary to wash ready-to-eat, prewashed and packaged fresh-cut produce. However, if produce is rewashed, follow the washing instructions mentioned above. Once prepared for eating, fruits and vegetables should be refrigerated until served; refrigerate leftovers within two hours.

Ready-To-Eat, Fresh-Cut Fruits and Vegetables

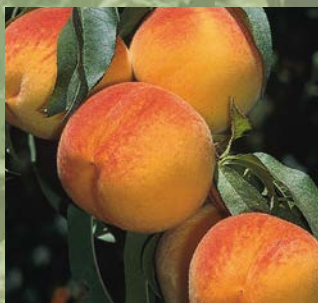
Having ready-to-eat fruit slices at home encourages everyone to eat more fruits, which are healthier than many processed snack foods. Fruit slices visually spoil due to brown discoloration and water-soaked appearance of the tissues caused by softening and juice leakage. This is usually associated with the development of off-flavors due to fermentation.

Eat cut fruits and vegetables within a week and before noticeable deterioration or off-odors. In general, whole and fresh-cut fruits look good longer than they taste good. (Flavor life is usually about two-thirds of appearance life.) Also, the longer the time between harvest and preparation of fruit slices, the shorter the post-cutting life. Buy the freshest fruits possible, slice, store in the refrigerator in plastic containers, and eat the fruit slices within a week after purchase. Select sliced fruits with the latest "use by" date on the package and eat them well before that date to assure better flavor and nutritional quality.

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