MATURITY, RIPENING, AND QUALITY RELATIONSHIPS OF FRUIT-VEGETABLES

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Summary

Maturity at harvest is the most important factor that determines postharvest-life and final quality (appearance, texture, flavor, nutritive value) of fruit-vegetables. Fruit-vegetables include two groups: (1) immature fruit-vegetables, such as green bell pepper, green chili pepper, cucumber, summer (soft-rind) squash, chayote, lima beans, snap beans, sweet pea, edible-pod pea, okra, eggplant, and sweet corn; and (2) mature fruit-vegetables, such as tomato, red peppers, muskmelons (cantaloupe, casaba, crenshaw, honeydew, persian), watermelon, pumpkin, and winter (hard-rind) squash. For group (1), the optimum eating quality is reached before full maturity and delayed harvesting results in lower quality at harvest and faster deterioration rate after harvest. For group (2) most of the fruits reach peak eating quality when fully ripened on the plant and, with the exception of tomato, all are incapable of continuing their ripening processes once removed from the plant. Fruits picked at less than mature stages are subject to greater shriveling and mechanical damage, and are of inferior flavor quality. Overripe fruits are likely to become soft and/or mealy in texture soon after harvest. The necessity of shipping mature fruit-vegetables long distances has often encouraged harvesting them at less than ideal maturity, resulting in suboptimal taste quality to the consumer.

Several factors in addition to maturity at harvest have major impacts on postharvest behaviour and quality of fruit-vegetables. Fruits of group (1) normally produce only very small quantities of ethylene. However, they are very responsive to ethylene and can be damaged by exposure to 1 ppm or higher concentrations. Ethylene exposure accelerates chlorophyll degradation, induces yellowing of green tissues, encourages calyx abscission (eggplant), and accelerates fruit softening. Most of the fruits in group (2) produce larger quantities of ethylene in association with their ripening, and exposure to ethylene treatment will result in faster and more uniform ripening as indicated by loss of chlorophyll (green color), increase of carotenoids (red, yellow, and orange colors), flesh softening and increased intensity of characteristic aroma volatiles. All fruit-vegetables, except peas and sweet corn, are susceptible to chilling injury if exposed to temperatures below 5°C (cantaloupe, lima bean, snap bean), 7.5°C (peppers), 10°C (cucumber, soft-rind squash, eggplant, okra, chayote), or 12.5°C (tomato, muskmelons other than cantaloupe, pumpkin, hard-rind squash). A relative humidity range of 90 to 95% is optimum for all fruit-vegetables except pumpkin and hard-rind squash where it should be 60 to 70%. Atmospheric modification (low oxygen and/or elevated carbon dioxide concentrations) can be a useful supplement to proper temperature and relative humidity in maintaining postharvest quality of some fruit-vegetables, such as tomato and muskmelons.

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1. Introduction

Fruit-vegetables can be classified according to their general characteristics and postharvest requirements for quality maintenance as follows:

1. *Immature fruit-vegetables*:
   a.Fleshy fruits: cucumber, soft-rind (summer) squash, eggplant, green pepper.
   b.Non-fleshy fruits: snap beans, lima beans, southern peas (cowpeas), peas, broad beans, sweet corn, okra.
2. *Mature fruit-vegetables*:
   a.Fleshy fruits: tomato, red pepper, hard-rind (winter) squash, pumpkin, muskmelons, watermelons.
   b.Non-fleshy fruits: dry peas, dry beans.

Tomatoes are the leading fresh market and processing fruit-vegetable in the world. Most melons are consumed fresh, while most legumes are consumed in a processed form (frozen, canned, or dried). Tomatoes rank number one among fruits and vegetables in relative contribution of vitamins A and C to human nutrition. Peppers are highest in vitamin C content among fruit-vegetables. Cantaloupes and other orange-flesh muskmelons rank high in their provitamin A content. Legumes are major contributors of protein, niacin, thiamine, and some minerals.

Genotype, cultural practices (Plant density, fertilization, irrigation, pest management), climatic conditions, maturity at harvest, and harvesting method influence composition and quality of fruit-vegetables at harvest. Subsequent maintenance of quality and reduction of losses depend upon postharvest handling conditions, especially temperature and relative humidity. Expedited handling, avoiding mechanical injuries, and use of appropriate sanitation procedures are also important in extending the postharvest-life of fruit-vegetables.

Maturity and Quality Indices

Although much effort has been devoted to identification of maturity indices that can be used to determine optimum harvest dates, only limited studies have dealt with the relationship between maturity and flavor quality. Appearance and textural quality have received much greater attention than flavor and nutritional quality. Often subjective rather than objective methods of maturity and quality evaluation are used. Quality factors and maturity indices for selected fruit-vegetables are summarized in Table 1.

To the grower, quality includes disease resistance, high yield, uniform maturity, desirable size, and ease of harvest. The shippers and handlers are concerned with shipping quality and market quality. The consumer cares mainly for table quality which includes appearance, texture, flavor, and nutritive value.

Maturity at harvest is very important to final quality to the consumer. For fruit-vegetables consumed immature, overmaturity results in inferior quality. Fruit-vegetables consumed ripe are best when ripened on the plant. Immaturity in this group results in inferior flavor quality and higher susceptibility to shriveling and mechanical damage.

Table 1. Quality factors for selected fruit-vegetables in the U.S. Standards for Grades and the California Food and Agricultural Code.

VEGETABLE	STANDARD (date issued)	QUALITY FACTORS
BEANS, Snap	US (1990)	Uniformity, size, maturity (not overmature = woody or fibrous), firmness (not wilted or flabby), no defects or decay.
CUCUMBERS,	US (1958)	Color, shape, size (diameter & length), turgidity, maturity, freedom from defects and decay.
greenhouse	US (1985)	Freshness, shape, size (length), firmness, color, freedom from decay, cuts, bruises, scars, insect injury, and other defects.
EGGPLANT	US (1953)	Color, turgidity, shape, size and freedom from defects and decay.
MELONS,		
Cantaloupe	US (1968)	Uniformity of size, shape, ground color and netting, maturity, soluble solids (>9%), turgidity, freedom from "wet slip", sunscald, and other defects.
	CA (1983)	Maturity (soluble solids >8%), freedom from bruises, sunburn, growth cracks, and decay.
Honeydew & Honey Ball	US (1967)	Maturity, firmness, shape, freedom from decay and defects (sunburn, bruising, etc.).
	CA (1983)	Maturity (soluble solids >10%), freedom from sunscald, bruises, growth cracks, and decay.
PEPPERS,		
Sweet	US (1989)	Maturity, color, shape, size, firmness, freedom from defects (sunburn, sunscald, freezing injury, hail scars, insect and mechanical damage) and decay.
	CA (1983)	Freedom from insect damage, bacterial spot, and decay.
TOMATOES	US (1991)	Maturity (contents of 2 or more seed cavities have developed a jelly-like consistency and the seeds are well developed), ripeness (color chart), firmness, shape, size, freedom from defects (mechanical injury, freezing injury, sunscald, scars, catfaces, growth cracks, insect injury, puffiness) and decay.
	CA (1983)	Mature but not overripe, free from defects and decay.
greenhouse,	US (1966)	Maturity, firmness, shape, size, freedom from decay, shriveling,sunscald, puffiness, catfaces, scars, growth cracks, and other defects.

Ripening

All mature fruit-vegetables reach their best eating quality when allowed to ripen on the plant. However, some mature fruit-vegetables (such as tomatoes) are often picked mature but unripe so that they can withstand the postharvest handling system when shipped long distance. Satisfactory ripening occurs only within the limits of about 15 to 25°C. The rate of ripening increases with temperature within that range. Optimum ripening temperatures are 20-22°C. Ethylene treatments (100 ppm for 24 to 48 hours) can be used to accelerate ripening and achieve more uniform ripening of mature-fruit vegetables. Commercial use is limited to mature-green tomatoes and, to a much lesser extent, honeydew melons.

Muskmelons have very little starch reserves and their sugar content increases only slightly (<15%) after harvest. Thus, it is important to harvest cantaloupes, honeydews, and other muskmelons at a fully-mature to partially-ripe stage when enough sugars have accumulated in the fruit. Ripening muskmelons soften, change in color (loss of green color and appearance of yellow color), and increase in aroma intensity, and attain good eating quality. Melons picked partially-ripe produce enough ethylene to complete their ripening and, consequently, postharvest ethylene treatment is not needed.

Watermelons should be picked when fully-ripe as indicated by the color (yellowing) of the ground spot, density (the heavier, the more sugars), and the sound of the fruit when thumped. Watermelons are detrimentally affected by ethylene above 0.5 ppm (they become spongy and their flesh becomes mealy and macerated with poor flavor).

Mature-green bell peppers do not change color (to red, yellow, or other cultivar-specific color) postharvest even when treated with ethylene. Color changes in bell peppers harvested partially-ripe; the higher the degree of coloration at harvest, the faster these peppers complete coloration after harvest (best temperature range is 20 to 25°C). Coloration of chili peppers is enhanced by postharvest ethylene treatment (similar to tomatoes).

Detrimental Effects of Ethylene

Exposure of watermelons and most of the immature-fruit-vegetables to ethylene accelerates their deterioration. Symptoms of ethylene injury include loss of green color (yellowing) of green beans, cucumber, and summer squash; calyx abscission and seed browning of eggplant; and flesh softening. The incidence and severity of ethylene induced deterioration symptoms depends upon temperature, exposure time, and ethylene concentration. For example, yellowing of cucumbers can result from exposure to 1 ppm ethylene for 2 days or to 5 ppm ethylene for 1/2 day at 10°C. Ethylene effects are cumulative throughout the postharvest life of the commodity.

Response to Controlled Atmospheres (CA)

Mature-fruit-vegetables show more beneficial responses to CA than immature-fruit-vegetables because of CA effects on delay of ripening. A 3 to 5% O_2-atmosphere without added CO_2 can be tolerated for this group of vegetables. Tolerance for elevated CO_2 varies among these vegetables. While tomatoes, bell peppers, and cucumbers may show CO_2 injury if exposed to more than 2% CO_2 for longer than 2 weeks, cantaloupes and sweet corn tolerate and benefit from 10-15% CO_2. CA or MA are not in common use on these commodities except during transport for export marketing (Table 2).

Table 2. Summary of recommended controlled atmosphere conditions during transport and/or storage of selected fruit-vegetables.

COMMODITY	Temperature range (°C)	Atmospheric composition %O_2	%CO_2	Commercial application (extent)
BEANS, Snap	5-10	2-3	4-7	
CORN, Sweet	0-5	2-4	5-10	Limited use during transport
CUCUMBER	8-12	2-4	<1	
MELON				
Cantaloupe	3-7	3-5	10-15	Limited use during transport
Honeydew	10-12	3-5	<1	Limited use during transport
OKRA	8-12	3-5	4-10	
PEA, Edible pod	0-5	2-3	2-3	
PEPPER,				
Bell	8-12	3-5	0-3	
Chili	8-12	3-5	0-3	
TOMATO,				
Mature-green	12-20	3-5	0-3	Limited use during transport
Partially-ripe	8-12	3-5	0-5	Limited use during transport

A relative humidity of 90 to 95% is recommended in all cases.

Major Causes of Postharvest Losses

1. *Physical damage* As a major source of losses in quantity and quality during marketing, physical damage increases with handling and is cumulative. Symptoms (cuts, punctures, abrasions, scuffing, brown discoloration of bruised tissues) may not be visible at shipping point, but become noticeable during subsequent handling handling steps. Injuries which damage skin are usually more severe on immature fruits and facilitate water loss and attack by decay-causing pathogens. Bruising and deformation are more severe on partially-ripe and ripe fruits. Vibration bruising during transportation can be minimized by immolilizing the fruits within shipping containers or consumer packages.
2. *Water Loss.* Fruit-vegetables, in general, have a low surface to volume ration and their susceptibility to water loss is moderate (compared to leafy and floral vegetables). Immature-fruit vegetables are more susceptible to water loss thatn mature-fruit vegetables. Cuticle thickness, presence of openings (such as stomata and very small cracks) and trichomes influence the rate of water loss. In tomatoes, about 65% of the water loss occurs through the stem scar.
3. *Chilling injury.* All fruit-vegetables (except broad beans, peas and sweet corn) are susceptible to chilling injury when exposed to temperatures above freezing and below 5 to 12°C depending on the specific commodity. Chilling injury can occur in the field, durign transportation, at the market, or in the home. The harmful effects are additive and accumulative. Symptoms of chilling injury are described in Table 3. Elevated CO_2 (5-10%) atmorspheres have been shown effective in alleviating chilling symptoms for chili peppers and okra. Ohter treatments such as intermittent warming, and calcium dips are also effective, but are not used commercially.

Table 3. Visual symptoms of chilling injury on selected fruit-vegetables.

VEGETABLE		SYMPTOMS
I.	**IMMATURE FRUITS**	
	BEANS, lima -	Rusty brown specks, spots, or areas--followed by decay.
	snap -	Surface pitting, diagonal brown streaks, dullness of normal surface color, discoloration of seeds, increased susceptibility to decay
	CUCUMBERS	Shallow surface pits of various sizes, water-soaked spots, increased decay.
	EGGPLANT	Pitting, brown surface areas which become sunken with time, calyx discoloration, flesh browning.
	OKRA	Discoloration, water-soaked areas, pitting, increased decay.
	PEPPERS, bell & chili	Numerous minute to fairly large, shallow, roundish surface depressions (sheet pitting), seed browning, calyx discoloration, alternaria rot incidence.
	SQUASH, summer	Surface pitting, rapid decay
II.	**MATURE FRUITS**	
	MUSKMELONS	Softening, pitting, increased decay incidence. For honeydew melons: failure to ripen, water-soaked rind, and in severe cases sticky surface due to juice exudation.
	PUMPKINS & WINTER SQUASH	Alternaria rot incidence.
	TOMATOES	Pitting, shriveling, softening, delayed and uneven ripening, seed discoloration, increased susceptibility to alternaria rot.
	WATERMELONS	Surface pitting and sunken areas which become dry upon removal to nonchilling temperature, internal rusty-brown spots on the rind, objectionable flavor.

2. Concluding remarks

Delivering high-quality fruit-vegetables to the consumer and reducing postharvest losses are possible by selecting good-flavored cultivars, using optimum cultural practices, picking the fruits at their optimum maturity, and using proper postharvest handling procedures. Much information is available on all these aspects. However, more research is needed to achieve the following goals:

1. Establishing minimum requirements for acceptable eating quality of each fruit-vegetable and developing nondestructive, objective evaluation methods of maturity and quality indices.
2. Producing new cultivars with superior flavor and nutritional quality, lower browning potential, and longer postharvest-life potential.
3. Reducing incidence and severity of physiological disorders, including chilling injury and ethylene damage using atmospheric modification, heat treatment, and/or other methods.
4. Developing a postharvest integrated pest management program for fruit-vegetables, with emphasis on alternatives to currently used fungicides/bactericides and fumigants for disease and insect control, respectively.

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