



Postharvest Biology & Handling of Vegetables


III. Immature & Mature Fruits

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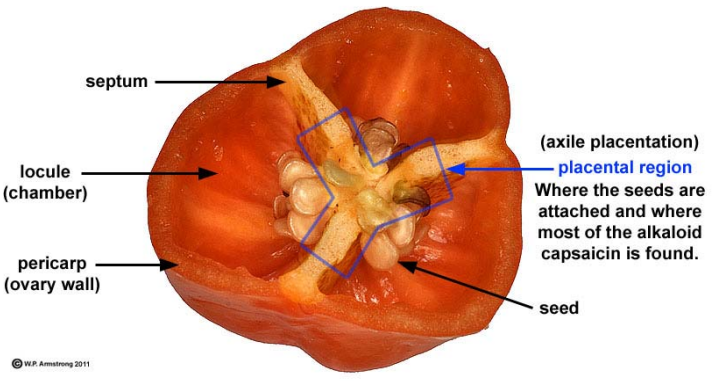



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I. Introduction

- **Fruit Vegetables:**
 - Vegetable that are botanically classified as a fruit
 - **Fruit** = the product of a ripening ovary and its associated tissue
 - May be consumed either:
 - **Immature** – e.g., cucumber & sweetcorn
 - **Mature** – e.g., tomato & watermelon



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<http://waynesword.palomar.edu/images2/habanero1c.jpg>

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I. Introduction

- **Classification is based on maturity at harvest:**

- Immature fruit vegetables

- **Fleshy fruits:** cucumber, summer squash, eggplant, bell pepper.



- **Non-fleshy fruits:** broad beans, lima beans, snap beans, okra, peas, southern peas (cowpeas), sweetcorn



<http://www.ams.usda.gov/farmersmarkets>

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Taxonomic Classification of Some Immature Fruit Vegetables




Common Name		Genus & Species
Dicots		
<i>Cucurbitaceae</i>		
	Bitter gourd	<i>Momordica charantia L.</i>
	Chayote	<i>Sechium edule (Jacq.) Sw.</i>
	Cucumber	<i>Cucumis sativus L.</i>
	Summer squash	<i>Cucurbita pepo L.</i>
<i>Leguminosae</i>		
	Broad bean	<i>Vicia faba L.</i>
	Green bean	<i>Phaseolus vulgaris L.</i>
	Lima bean	<i>Phaseolus lunatus L.</i>
	Garden pea	<i>Pisum sativum L.</i>
	Snow pea	<i>Pisum sativum L.</i>
<i>Malvaceae</i>		
	Okra	<i>Abelmoschus esculentus L.</i>
<i>Solanaceae</i>		
	Eggplant	<i>Solanum molengena L.</i>
Monocots		
<i>Gramineae</i>		
	Sweetcorn	<i>Zea mays L.</i>

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I. Introduction

- **Classification is based on maturity at harvest:**
 - Mature fruit vegetables:
 - **Fleshy fruits:** colored bell pepper (Capsicum), muskmelons, pumpkins, winter squash, tomato, watermelons
 - **Non-fleshy fruits:** dry beans, dry peas











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Taxonomic Classification of Some Mature Fruit Vegetables

Common Name	Genus & Species
<i>Curcubitaceae</i>	
Winter squashes	<i>Cucurbita maxima & argyrosperma</i>
Netted muskmelon, cantaloupe, Persian melon	<i>Cucumis melo</i>
Pumpkin, acorn squash, ornamental gourds	<i>Cucurbita pepo L.</i>
Watermelon	<i>Citrullus lanatus</i>
<i>Solanaceae</i>	
Tomato	<i>Lycopersicon esculentum</i>
Pepper	<i>Capsicum annuum</i>



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Comparison of Postharvest Characteristics of Immature & Mature Fruit Vegetables

Immature Fruit Vegetables	Mature Fruit Vegetables
Warm-season crops (except peas & broad beans)	Warm-season crops
Chilling sensitive (except peas, broad beans, & sweetcorn)	Chilling sensitive
High-to-very-high respiration rates	Low-to-moderate respiration rates
Rapidly developing	Completing or completed development
Nonclimacteric	Some are climacteric
Morphological changes after harvest are detrimental	Morphological changes after harvest may be desirable
Chlorophyll loss is detrimental	Chlorophyll loss & pigment synthesis may be desirable



Postharvest Physiology & Pathology of Vegetables, 2nd Ed (2003)

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I. Introduction

- **Tomato is the leading fresh market vegetable in the U.S.**
 - About 1/3 each from California, Florida and Mexico
- **Florida leads the nation in production of many of these crops (warm season crops grown in the winter):**
 - Snap beans, cucumbers, summer squash, sweetcorn, and watermelons



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I. Introduction

- **Fresh market vs. processing**

- Many in this group are processed (canned or frozen)
 - Beans, sweetcorn, cucumber (pickles), peas, squash, tomato
 - Consumption is greater in processed forms, especially tomatoes (sauce, paste, juice, ketchup, salsa, dried)
- Melons are consumed mostly fresh (including fresh-cut)



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II. Morphological Characteristics

- The growth pattern is a simple sigmoidal curve.
 - Immature fruit vegetables are harvested when the edible part is partially developed; at the optimum horticultural maturity for the individual crop
 - Mature fruit vegetables are harvested when full size is reached, or the seed coat has developed, or when ripening has commenced



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II. Morphological Characteristics

- **In relation to water loss:**

- Cuticle thickness, presence of openings and trichomes control water loss
 - *e.g.*, ~85% of tomato water loss is through the stem scar
- Low surface:volume ratio = moderate water loss
- Immature-harvested types have thinner cuticles and are thus more susceptible to water loss than mature types



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II. Morphological Characteristics

- **In relation to texture:**

- Flesh firmness and skin toughness are important to texture of fleshy fruit vegetables
- Fiber sheath (elongated sclereids) responsible for toughness in bean pods
- Hard rind of winter squash and pumpkins is due to sclerenchyma.



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III. Compositional Characteristics

- Tomatoes rank No. 1 in contribution to nutrition in the U.S. diet
- Cantaloupes are high in vitamin A contribution
- Peppers are the highest in vitamin C among this group (128 mg 100 g FW⁻¹)
 - >twice the amount found in citrus fruit
- Legumes are major contributors of protein, niacin, thiamine and minerals



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IV. Physical Damage

- A major source of losses in quantity and quality during postharvest handling and marketing
- Increases with increased handling and is cumulative
- Symptoms may not be visible at shipping point, but become noticeable during transit and subsequent handling



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IV. Physical Damage

- Injuries that damage skin tissues (cuts, punctures, abrasions, scuffing) are usually more serious on immature fruits and lead to decay



Photo courtesy of Steve Sargent

- Bruising and deformation are more severe on partially-ripe and ripe fruits



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V. Maturity & Quality Indices

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



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V. Maturity & Quality Indices

- Maturity at harvest is very important to final quality for the consumer
 - For fruits consumed immature, overmaturity results in inferior quality
 - Fruits consumed ripe are best when ripened on the plant, and immaturity results in inferior quality
- Quality factors and maturity indices that are used in the U.S. Standards for Grades for selected fruit vegetables are summarized in the following tables:



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Quality Factors for Selected Fruit Vegetables in the U.S. Standards for Grades



Vegetable	Quality factors
Cantaloupes	Uniformity of size, shape , ground color and netting, maturity , soluble solids (>9%), turgidity, freedom from “wet slip”, sunscald, and other defects
Honeydew Honey Ball type melons	Maturity , firmness, shape , freedom from defects (sunburn, & bruising, etc.) and decay
Watermelons	Maturity, shape , uniformity of size (weight), freedom from anthracnose, decay , sunscald, white heart, and other defects . Optional internal quality criteria: SSC 10% (very good), 8% (good)

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Quality Factors for Selected Fruit Vegetables in the U.S. Standards for Grades



Vegetable	Quality factors
Tomatoes	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
Beans, snap	Uniformity, size, maturity freshness (firmness), freedom from defects and decay
Cucumbers	Color, shape, size (diameter & length), turgidity, maturity, freedom from defects and decay
Sweetcorn	Uniformity of color & size , freshness, milky kernels, cob length, freedom from defects , coverage with fresh husks

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VI. Postharvest Physiology

- **Respiration and ethylene production:**
 - Most of these fruit vegetables are nonclimacteric.
 - Tomatoes and cantaloupes are the only climacteric fruits in the group
 - Honeydew cvs do not exhibit a consistent climacteric
 - Respiration rates vary from very high (more than 100 mg CO₂/kg h at 10°C) for sweetcorn and peas to low (less than 10 mg CO₂/kg h at 10°C) for honeydew and watermelon



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Respiration rates for selected fruit vegetables



Class	(mg CO ₂ /kg-hr) at 5 °C (41 °F)	Commodities
Low	5 -10	Honeydew melon, watermelon
Moderate	10 - 20	Cantaloupe, cucumber, summer squash, tomato
High	20 - 40	Lima bean
Very High	40 -60	Okra, snap bean
Extremely High	> 60	Peas, sweetcorn

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VI. Postharvest Physiology

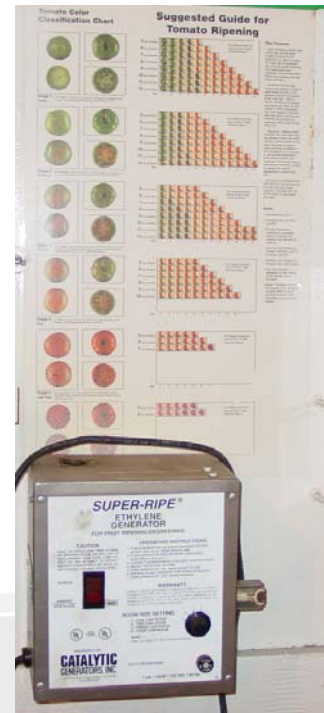
- Ethylene production:
 - Ethylene production rates are very low (less than 0.1 uL/kg h) in nonclimacteric and unripe fruits.
 - Ethylene production rates may reach high levels (more than 20 uL/kg h) in ripening tomatoes and cantaloupes.
 - Exposure to ethylene is detrimental to immature fruit vegetables (causes yellowing and senescence).



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VI. Postharvest Physiology

- Control of ripening (climacteric fruits harvested mature):
 - Satisfactory ripening occurs only within the limits of about 12 to 25°C
 - The rate of ripening increases with temperature within that range
 - Optimum ripening temperatures are 20-22°C



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VI. Postharvest Physiology

- Control of ripening (climacteric fruits harvested mature):
 - Ethylene treatments (100 ppm for 24-48 h) can be used to accelerate ripening and achieve more uniform ripening of mature climacteric fruit
 - Commercial use is limited to mature-green tomatoes and Honey Dew melons (cantaloupes are always harvested vine-ripe)
 - Reduced O₂ between 3% and 5% can be used to retard ripening (see below).



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VI. Postharvest Physiology

- Responses to controlled atmospheres:
 - 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% O₂ atmosphere without added CO₂ can be tolerated for this group of vegetables as a whole.



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VI. Postharvest Physiology

- Tolerance of elevated CO₂ varies among these vegetables:
 - Tomatoes, bell peppers, and cucumbers may show CO₂ injury if exposed to >2-5% CO₂
 - Snap beans, okra and chili peppers tolerate and benefit from 5-10% CO₂
 - Cantaloupes and sweetcorn tolerate and benefit from 10-15% CO₂




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VI. Postharvest Physiology

- Responses to controlled atmospheres:
 - Carbon monoxide (5 to 10%) added to 3-5% O₂ is effective for decay control on tomatoes
 - CA and MA are not in common use on these commodities except for international marketing




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VI. Postharvest Physiology

- Physiological disorders: **Chilling injury**
 - Most fruit vegetables are susceptible to chilling injury when exposed to temperatures above freezing and below 5 to 12°C depending on the commodity
 - Broad beans, peas and sweetcorn are exceptions in that they are not chilling sensitive




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VI. Postharvest Physiology

- Physiological disorders: **Chilling injury**
 - Chilling injury can occur in the field, in storage, during transportation, at the distribution center or market, and in the home
 - The harmful effect is **additive** and **cumulative**.

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VI. Postharvest Physiology

- Physiological disorders: **Chilling injury**
 - Elevated CO₂ (5-10%) atmospheres have been shown effective in alleviating chilling symptoms for chili peppers and okra
 - Intermittent warming, heat treatments, and calcium dips are also effective in reducing chilling injury, but are not used commercially.

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Visual Symptoms of Chilling Injury on Selected Fruit Vegetables

Vegetable	Symptoms
Beans	Surface pitting , diagonal brown streaks, dullness of normal surface color, discoloration of seeds , increased susceptibility to decay
Cucumbers	Shallow surfaces pits of various sizes, water-soaked spots, and increased decay
Eggplant	Pitting : brown surface areas that become sunken with time; calyx discoloration, and flesh browning
Peppers, bell and chili	Numerous minute to fairly large, shallow, roundish surface depressions (sheet pitting), seed browning , and calyx discoloration
Okra	Discoloration, water-soaked areas, pitting, and increased calyx discoloration
Squash, summer	Surface pitting and rapid decay



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Visual Symptoms of Chilling Injury on Selected Fruit Vegetables

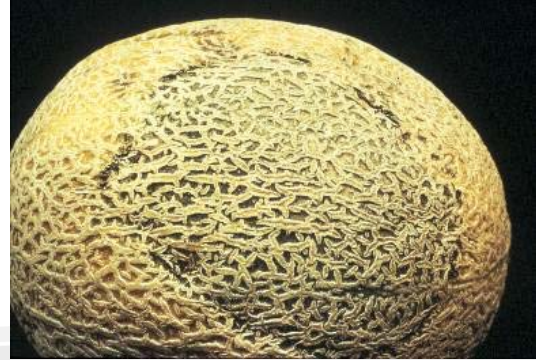
Vegetable	Symptoms
Muskmelons	Softening, pitting , and increased decay incidence. For Honey Dews: failure to ripen, water-soaked rind, and sticky surface due to juice exudation in severe CI
Pumpkins and winter squash	Alternaria rot incidence
Tomatoes	Pitting , shriveling, softening, delayed and uneven ripening, increased susceptibility to Alternaria rot, and seed discoloration . Susceptibility decreases with ripening
Watermelons	Surface pitting and sunken areas that become dry upon removal to nonchilling temperature, internal rusty-brown spots on the rind, fading of red flesh color, and objectionable flavor



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VI. Postharvest Physiology

- Other physiological disorders:
 - **Freezing injury** (immature fruit vegetables are more susceptible)
 - **Solar injury** (sunburn, sunscald). Use of whitewash in the field (water suspension of aluminum silicate and a surfactant).



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VI. Postharvest Physiology

- Other physiological disorders:
 - **Blotchy and irregular ripening** of tomatoes (related to nutritional imbalance and virus, respectively)
 - **Graywall** of tomatoes (browning of the underlying vascular system; high N/K ratio, high temp., microbes)



<http://www.umassvegetable.org>



vegetablemndonline.ppath.cornell.edu



<https://plantpath.ifas.ufl.edu/>

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VI. Postharvest Physiology

- Other physiological disorders:
 - **Blossom-end rot** of tomatoes, peppers, and watermelons – related to water stress and calcium deficiency
 - **Growth cracks** (related to fluctuating water levels)



aggie-horticulture.tamu.edu

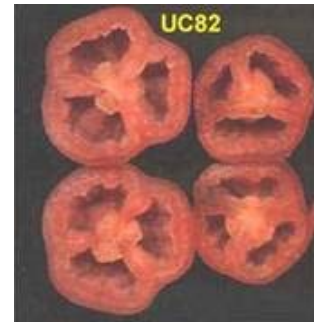


<http://postharvest.ucdavis.edu>

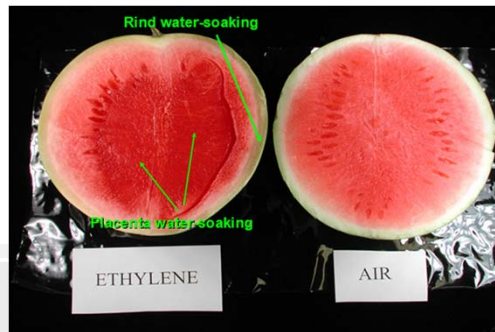
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VI. Postharvest Physiology

- Other physiological disorders:
 - **Puffiness** of tomatoes (related to poor pollination)
 - **Internal rind spot** on watermelons due to drought stress
 - **Watersoaking** due to ethylene



<http://www.agri.gov.il>



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VI. Postharvest Physiology



- Other physiological disorders:
 - **Yellowing** of cucumbers and green squash varieties (ethylene related)



<http://postharvest.ucdavis.edu>

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VII. Pathological Breakdown

- **Anthracnose** (snap beans, cucumber, watermelon)
- **Watery soft rot** caused by *Sclerotinia spp* (snap beans)
- **Bacterial soft rot** (cucurbits, tomatoes, eggplant, peppers, melons)
- **Cottony leak** caused by *Pythium spp.* (snap bean, cucumber, squash)
- **Alternaria rot** – usually follows chilling injury



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VII. Pathological Breakdown

- **Gray mold** rot (peas, peppers, tomatoes).
- **Rhizopus rot** (peppers, melons, tomatoes, pumpkins).
- **Fusarium rot** (melons, tomatoes, pumpkins).
- **Phytophthora rot** (tomato, watermelon).
- **Cladosporium rot** (melons, peppers).



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VIII. Postharvest Handling Procedures

- **Harvesting:**
 - Fruit vegetables harvested immature for the fresh market are **mostly hand-harvested**
 - Sweetcorn, snap beans and peas are harvested mechanically for both fresh market and processing.



<http://www.hinkleproduce.com/corn.html>

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VIII. Postharvest Handling Procedures

- **Harvesting:**

- All fruit vegetables that are harvested mature for marketing fresh are harvested by hand. Some harvesting aids may be used (*i.e.*, melon pick-up machines, conveyors, etc.)



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VIII. Postharvest Handling Procedures

- **Harvesting:**

- Pickling cucumbers, pod vegetables, and tomatoes for processing are mechanically harvested



- **Hauling** to the packinghouse or processing plant and unloading



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VIII. Postharvest Handling Procedures

- **Preparation for market and marketing:**

- **Cleaning**
- **Sorting** to eliminate defects
- **Waxing** (tomato, pepper, cucumber)
- **Sizing**
- **Packing** - shipping containers
- **Unitization** and **Palletization**



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VIII. Postharvest Handling Procedures

- **Preparation for market and marketing:**

- **Cooling**
- Temporary **storage**
- **Loading** into transport vehicles
- **Destination handling** (distribution centers, wholesale markets, etc.)
- **Delivery** to retail
- **Retail** handling



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VIII. Postharvest Handling Procedures

• Cooling:

- Most of the immature fruit vegetables plus (rarely) tomatoes may be **hydrocooled**
 - Peppers are not hydrocooled because of infiltration of water into the internal cavity
- The mature, fleshy fruits may be forced-air cooled
- Immature, non-fleshy fruit vegetables are not forced-air cooled due to shriveling



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VIII. Postharvest Handling Procedures

• Special treatments:

- **Ripening** (use of ethylene)
 - May be applied at shipping point, in transit or at destination
- Use of **modified and controlled atmospheres**
 - Used in marine transit applications only
 - Tomatoes, peppers, muskmelons, snap beans, sweetcorn




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IX. Recommended Conditions

- **Immature fruit vegetables:**
 - All are sensitive to chilling injury **except** broad beans, peas, and sweetcorn, which are best kept at 0°C and 95% RH.
 - **Optimum temperatures:**
 - Eggplant, peppers, cucumber, soft-rind squash, okra: 10-12°C
 - Lima beans, snap beans, cowpeas: 4-8°C
 - **Relative humidity range:** 90-95%.

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IX. Recommended Conditions

- **Mature fruit vegetables:**
 - All are sensitive to chilling injury.
 - **Optimum temperatures:**
 - Mature-green tomatoes, pumpkins and hard-rind squash: 12-14°C
 - Partially-ripe tomatoes, muskmelons (except cantaloupes): 10-12°C
 - Fully-ripe tomatoes, watermelons: 8-10°C
 - Cantaloupes: 3-5°C
 - **Relative humidity range:** 85-95%
Except pumpkins and hard-rind squashes: 60-70%

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IX. Recommended Conditions

- **Mature fruit vegetables**

- Compatibility considerations

- Avoid **mixing chilling-sensitive commodities with others** that are held or shipped at $<8^{\circ}\text{C}$ unless transit periods are <2 days
 - Ripening **tomatoes and melons produce ethylene**, which can influence ripening rates of other commodities and enhance yellowing of immature green fruits
 - If MA or CA are used, **O_2 should not be below 3% and CO_2 should not be above 2%** as general rules

