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

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
I. Introduction

Classification is based on maturity at harvest:

- Mature fruit vegetables:
  - Fleshy fruits: colored pepper (Capsicum), muskmelons, pumpkins, winter squash, tomato, watermelons
  - Non-fleshy fruits: dry beans, dry peas

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### Taxonomic Classification of Some Immature Fruit Vegetables

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Genus &amp; Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bitter gourd</td>
<td>Momordica charantia L.</td>
</tr>
<tr>
<td>Chayote</td>
<td>Sechium edule (Jacq.) Sw.</td>
</tr>
<tr>
<td>Cucumber</td>
<td>Cucumis sativus L.</td>
</tr>
<tr>
<td>Summer squash</td>
<td>Cucurbita pepo L.</td>
</tr>
<tr>
<td>Broad bean</td>
<td>Vicia faba L.</td>
</tr>
<tr>
<td>Green bean</td>
<td>Phaseolus vulgaris L.</td>
</tr>
<tr>
<td>Lima bean</td>
<td>Phaseolus lunatus L.</td>
</tr>
<tr>
<td>Golden pea</td>
<td>Pisum sativum L.</td>
</tr>
<tr>
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</thead>
<tbody>
<tr>
<td>Winter squash</td>
<td>Cucurbita maxima &amp; argyrosperma</td>
</tr>
<tr>
<td>Netted muskmelon, cantaloupe, Persian melon</td>
<td>Cucurbita melo</td>
</tr>
<tr>
<td>Pumpkin, acorn squash, ornamental gourds</td>
<td>Cucurbita pepo L.</td>
</tr>
<tr>
<td>Watermelon</td>
<td>Citrus lanus</td>
</tr>
<tr>
<td>Black bean</td>
<td>Vigna mungo</td>
</tr>
<tr>
<td>Tomato</td>
<td>Lycopersicon esculentum</td>
</tr>
<tr>
<td>Pepper</td>
<td>Capsicum annuum</td>
</tr>
</tbody>
</table>
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

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)
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.

Simple sigmoid growth curve showing the stage of growth when some fruit vegetables and others are harvested.

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.
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.

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)
  – Twice the amount found in citrus fruit
• Legumes are major contributors of protein, niacin, thiamine and minerals

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
IV. Physical Damage

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

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.

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

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Quality factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cantaloupes</td>
<td>Uniformity of size, shape, ground color and netting, maturity, soluble solids (&gt;9%), turgidity, freedom from “wet slip”, sunscald, and other defects</td>
</tr>
<tr>
<td>Honeydew</td>
<td>Maturity, firmness, shape, freedom from defects (sunburn, &amp; bruising, etc.) and decay</td>
</tr>
<tr>
<td>Honey Ball type melons</td>
<td>Maturity, shape, uniformity of size (weight), freedom from anthracnose, decay, sunscald, white heart, and other defects</td>
</tr>
<tr>
<td>Watermelons</td>
<td>Maturity, shape, uniformity of size (weight), freedom from anthracnose, decay, sunscald, white heart, and other defects</td>
</tr>
</tbody>
</table>

Optional internal quality criteria: SSC 10% (very good), 8% (good)

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

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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Tomatoes</td>
<td>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</td>
</tr>
<tr>
<td>Beans, snap</td>
<td>Uniformity, size, maturity (firmness), freedom from mechanical injury, freezing injury, sunscald, scars, catfaces, growth cracks, insect injury, puffiness and decay</td>
</tr>
<tr>
<td>Cucumbers</td>
<td>Color, shape, size (diameter &amp; length), turgidity, maturity, freedom from defects and decay</td>
</tr>
<tr>
<td>Sweetcorn</td>
<td>Uniformity of color &amp; size, freshness, milky kernels, cob length, freedom from defects, coverage with fresh husks</td>
</tr>
</tbody>
</table>

## 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 CO\(_2\)/kg h at 10°C) for sweetcorn and peas to low (less than 10 mg CO\(_2\)/kg h at 10°C) for honeydew and watermelon.
Respiration rates for selected fruit vegetables

<table>
<thead>
<tr>
<th>Class</th>
<th>(mg CO₂/kg-hr) at 5°C (41°F)</th>
<th>Commodities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>5-10</td>
<td>Honeydew melon, watermelon</td>
</tr>
<tr>
<td>Moderate</td>
<td>10-20</td>
<td>Cantaloupe, cucumber, summer squash, tomato</td>
</tr>
<tr>
<td>High</td>
<td>20-40</td>
<td>Lima bean</td>
</tr>
<tr>
<td>Very High</td>
<td>40-60</td>
<td>Okra, snap bean</td>
</tr>
<tr>
<td>Extremely High</td>
<td>&gt;60</td>
<td>Peas, sweetcorn</td>
</tr>
</tbody>
</table>

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).

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
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 (via MA or LPS) between 3% and 5% can be used to retard ripening (see below).

• 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.

• Tolerance of elevated CO₂ varies among these vegetables:
  – Tomatoes, bell peppers, and cucumbers 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.
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

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

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
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.

Visual Symptoms of Chilling Injury on Selected Fruit Vegetables

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

Visual Symptoms of Chilling Injury on Selected Fruit Vegetables

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muskmelons</td>
<td>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</td>
</tr>
<tr>
<td>Pumpkins and winter squash</td>
<td>Alternaria rot incidence</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>Pitting, shriveling, softening, delayed and uneven ripening, increased susceptibility to Alternaria rot, and seed discoloration. Susceptibility decreases with ripening</td>
</tr>
<tr>
<td>Watermelons</td>
<td>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</td>
</tr>
</tbody>
</table>
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).

- Blotchy and irregular ripening of tomatoes (related to nutritional imbalance and virus, respectively)
- Graywall of tomatoes (browning of the underlying vascular system)

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

http://www.umassvegetable.org
http://vegetablemdonline.ppath.cornell.edu
http://aggiehorticulture.tamu.edu
http://postharvest.ucdavis.edu
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

VI. Postharvest Physiology

• Other physiological disorders:
  – Yellowing of cucumbers and green squash varieties (ethylene related)

http://postharvest.ucdavis.edu

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)
• Cottonty leak caused by Pythium spp. (snap bean, cucumber, squash)
• Alternaria rot – usually follows chilling injury
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).

VIII. Postharvest Handling Procedures

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

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

- 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 machine, conveyors, etc.
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

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

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
**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

- **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

**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, 10-12°C
    - Soft-rind squash, okra: 24°C
    - Lima beans, snap beans, cowpeas: 4-8°C
  - **Relative humidity range:** 90-95%. 
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%

- **Compatibility considerations**
  - Avoid mixing chilling-sensitive commodities with others that are held or shipped at <8°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, O₂ should not be below 3% and CO₂ should not be above 2% as general rules