# Special Treatments to Maintain Quality:  Color & Texture

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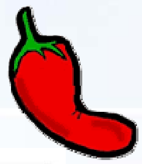
## Fresh-Cut Shelf Life Limitations

- Microbial spoilage
- Color *
  - Enzymatic (oxidative) browning
  - Loss of color, bleaching
- Texture *
  - Dessication – loss of moisture
  - Loss of cell integrity/translucency
- Flavor
  - Off-flavor or off-odor development
- Nutrients
  - Oxidation or change in biological activity

* Presentation will focus on these attributes.

Photo courtesy of Jim Gorny.

# Off-flavor and odor production

# Fresh – Cut Fruit & Vegetable Color

## Enzymatic browning in cut apples

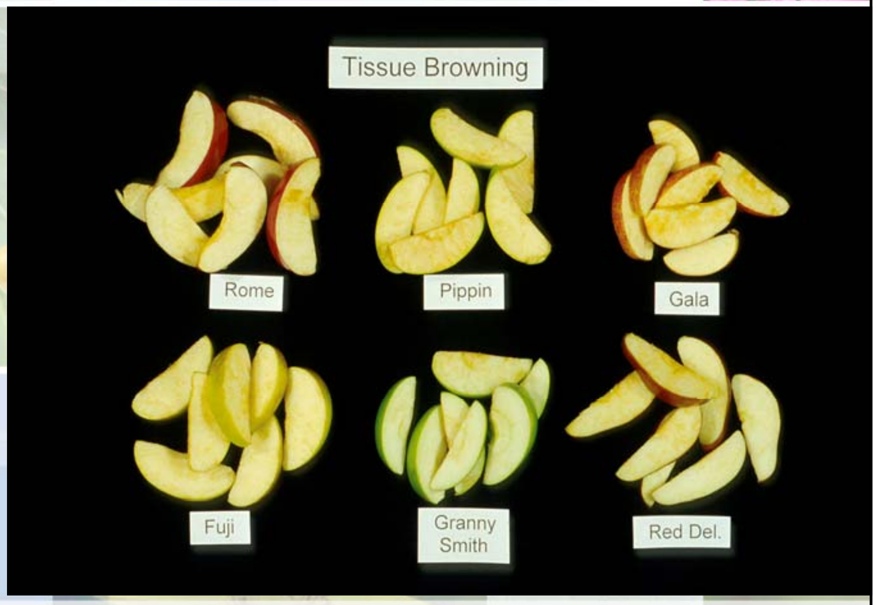
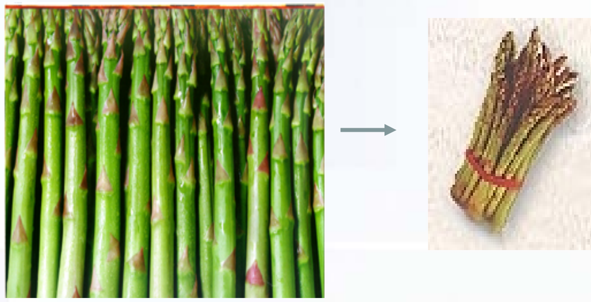



Photo courtesy of Adel Kader.

## Enzymatic browning in lettuce

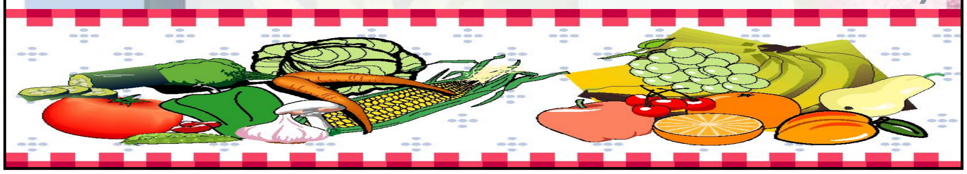

Photos courtesy of Jim Gorny.

## Loss of color - bleaching



## Fruit & Vegetable Color

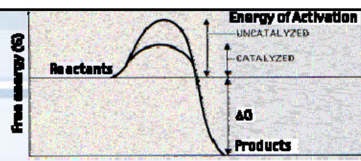
- **Water soluble**
  - Green — chlorophyll
  - Red to purple — anthocyanins
  - Brown, grey, black pink — phenolics
- **Fat soluble**
  - Yellow, orange, red — carotenoids (ex: lycopene, beta-carotene)



# Types of Browning

- <u>Enzymatic</u>
  - Polyphenol oxidase catalyzed
- <u>Non-Enzymatic</u>
  - Maillard
    sugar-amine reaction, concentrated solutions
  - Carmelization
    sugars, high temperatures
  - Ascorbic acid
    oxidation of ascorbic acid
  - Lipid browning

# Enzymes

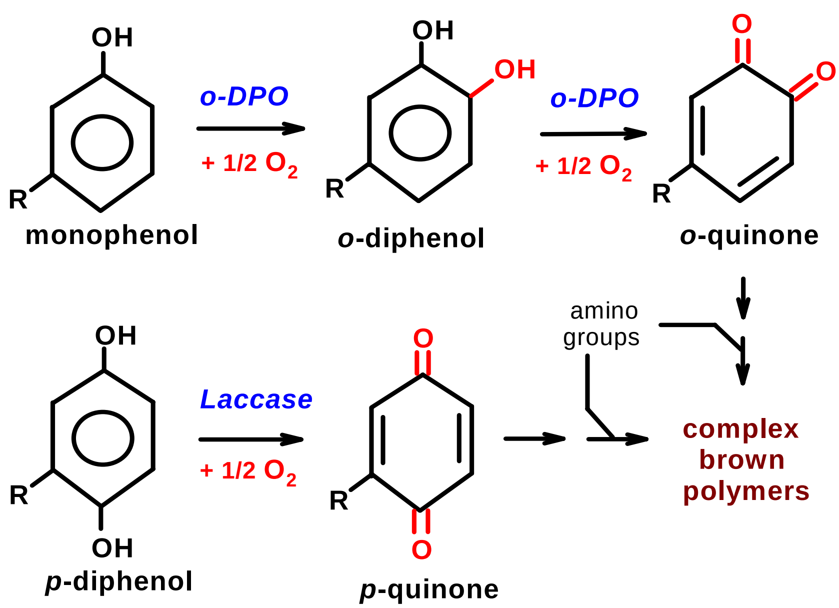



- Proteins - catalyze reactions by lowering activation energy
- Found naturally in plants, animals and microorganisms
- Responsible for metabolic processes, many reactions which result in quality loss
- Sensitive to temperature, pH, oxygen, light and substrate concentration

# Polyphenol oxidase (PPO)

•Two enzyme types - catalyze oxidation of
-mono-phenolics: o-diphenoloxidases
-di-phenolics: laccases
to form brown compounds

- Requires oxygen for reaction
- In plants, active pH range 6 to 7
- Contains copper as prosthetic group
- Somewhat heat unstable
- Enzyme localized in plastids, while substrates (phenolics) are in vacuole
- Genes have been cloned



## Phenylalanine Ammonia Lyase

- Key enzyme in phenolic biosynthesis
- Mechanical injury (wounding) and ethylene can stimulate phenolic metabolism
- Phenolics are substrates for PPO; increased concentration stimulates browning

## Factors Affecting PPO Activity

- Cultivar
- Maturity
- Tissue
- Phenolics present
- pH, oxygen, temperature, light
- Mechanical damage

## Apricot cultivars - Lightness differences

(oxidized - unoxidized) After Radler, 1997

| Cultivar | DL* |
|---|---|
| Henderson | 26.3 |
| Moniqui | 21.4 |
| Rouge de Roussillon | 17.8 |
| Rouge de Fournes | 17.8 |
| Polonais | 16.8 |
| Canino | 16.7 |
| Cafona | 11.8 |
| Bebeco | 5.3 |
| Precoce de Tyrinthe | 3.7 |

## Relative PPO activity- apple cultivars

| Cultivar | Relative PPO activity Peel | Cortex |
|---|---|---|
| Red Delicious | 100 | 100 |
| Golden Delicious | 33 | 30 |
| McIntosh | 46 | 80 |
| Fuji | 57 | 71 |
| Gala | 30 | 48 |
| Granny Smith | 43 | 73 |
| Jonagold | 43 | 43 |
| Elstar | 10 | 20 |

## Prevention of Enzymatic Browning

– Physical
- reduction of temperature and/or oxygen, use of
  - refrigeration
  - controlled atmospheres
  - modified atmosphere packaging
  - edible coatings
- treatment with heat, gamma-irradiation or high pressure

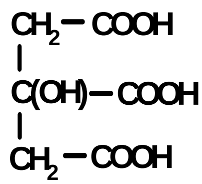
– Chemical means utilize compounds which act to
  - inhibit the enzyme
  - remove its substrates (oxygen and phenolics)
  - function as preferred substrate.

## Chemical Anti-browning Agents

- Acidulants
- Reducing Agents
- Chelating Agents
- Complexing Agents
- Enzyme Inhibitors

## Acidulants

- pH optimum for PPO is 6.0-6.5
- Little activity is detected below pH 4.5 (Whitaker 1994)
- Irreversible inactivation may occur at pH < 3.0
- Usually used in common with other agents
- Common acidulants:
  citric acid, malic acid



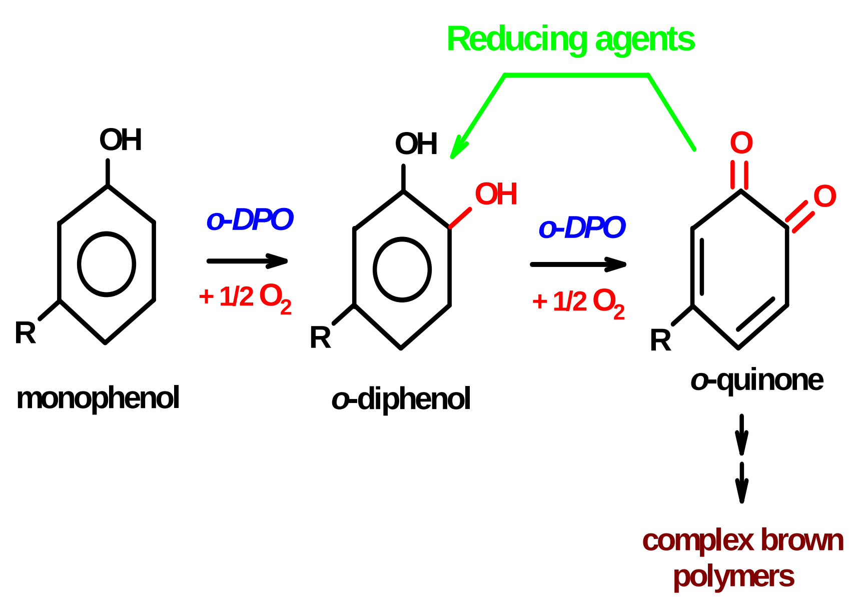

### Citric acid

Inhibits PPO by reducing pH and chelating copper prosthetic group.
Also inhibits oxidation by chelating other metal ions.

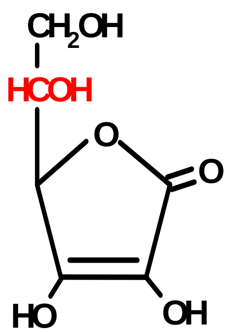
- synergistic with ascorbic acid

# Reducing Agents

- Causes reduction of colorless o-quinones resulting from PPO action back to o-diphenols
- Reducing agent is irreversibly oxidized; therefore consumed
- Common reducing agents:
  ascorbic acid, cysteine or other thiols



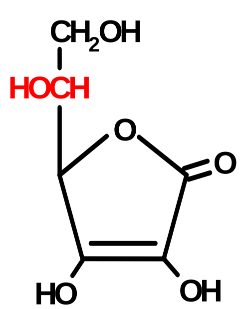
## Ascorbic acid




**Reduces quinones to phenolic compounds**

- acid and salt forms used
- salt (neutral pH) form may be more active
- water soluble
- often used in combination with citric acid

## Erythorbic Acid




**Reduces quinones to phenolic compounds**

- Isomer of ascorbic acid
- Acid and sodium salt used
- Sodium salt may be more effective
- Cheaper (1/5 cost) than ascorbic acid

## Chelating Agents

- Agents complex copper in the active site of PPO, therefore inhibit the enzyme
- <u>Common chelating agents</u>:
  EDTA, Sporix

## Complexing Agents

- Agents capable of entrapping or forming complexes with PPO substrates or reaction products
- Results vary with specific cyclodextrin and more complex mixtures of phenolics
- <u>Common complexing agents</u>:
  cyclodextrins
  cyclic nonreducing
  oligosaccharides

## Enzyme Inhibitors

- Sulfites inhibit PPO, but banned on use in fresh fruits and vegetables.
- One of inhibitors with the most potential is 4-hexyl resorcinol
- FDA GRAS status for shrimp only
- Additional approval requires testing on commodity of interest
- Used in combination with ascorbic acid

$Na_2SO_3$

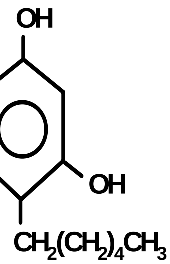
$NaHSO_3$

$SO_2$

**Sulfites**

**Inhibit polyphenol oxidase**
**React with PPO intermediates to form colorless products**

- no longer GRAS for fruits & vegetables served raw, sold raw or presented to customer as raw
- foods containing detectable level of sulfiting agent (10 ppm) must label contents




## 4-Hexylresorcinol

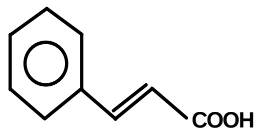
**Inhibits polyphenol oxidase**

- approved for use on shrimp to control browning

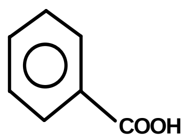
# Substrate Analogs

- **These agents inhibit PPO by mimicking phenolic substrates**
- **Over prolonged storage (>24 hr), Sapers et al. (1998) found severe browning developed.**
- **Suggested that cinnamates and benzoates undergo slow but gradual conversion to PPO substrates**

## Cinnamic Acid & Benzoic Acid




*t*-cinnamic acid

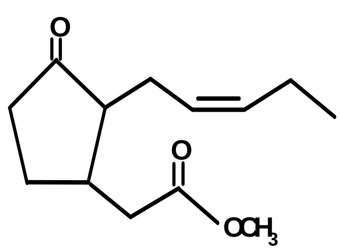



benzoic acid

**Inhibit o-diphenol oxidase by acting as substrate analogues**

- approved for food use

## Methyl jasmonate




**Inhibits browning**

- natural plant product
- very slightly soluble in water (soluble in alcohol)
- can be applied as gas

## Other Anti-browning Agents

1. Polyvinylpolypyrollidone (PVPP)
   Binds phenolic compounds. Is insoluble. Approved for apple juice fining agent.
2. Carbon monoxide
   Inhibits PPO by binding to copper in prosthetic group. Approved but is dangerous to handle during treatment.
3. Pineapple juice
   Sulfur compound appears to be a natural inhibitor of PPO. More research being conducted at Oregon State University.

## Physical methods
## Prevention of enzymatic browning

- Exclusion of oxygen
  (CA, MAP, edible coatings, sugar, salt)
- Temperature reduction
- Heat
- Gamma irradiation
- High pressure
- Pulsed electric fields

## Fresh – Cut Fruit & Vegetable Texture

## Dessication in cut carrots

Photo courtesy of Jim Gorny.

## Loss of integrity/translucency

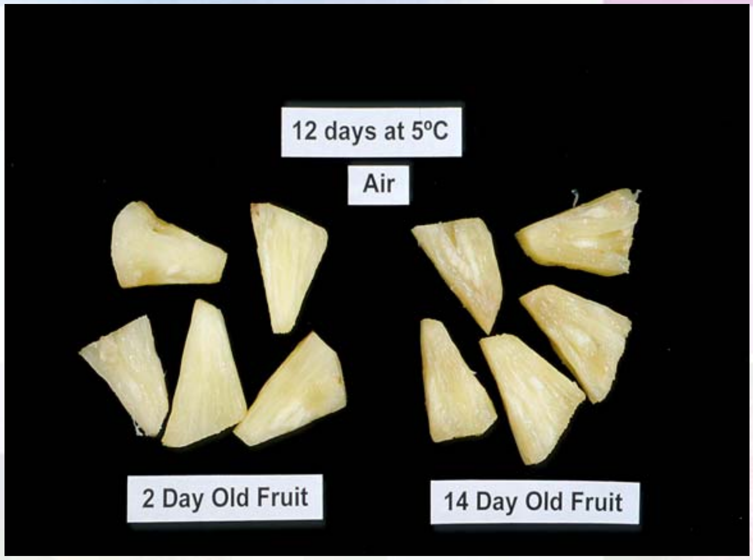



Photo courtesy of Adel Kader.

## Dessication - loss of integrity

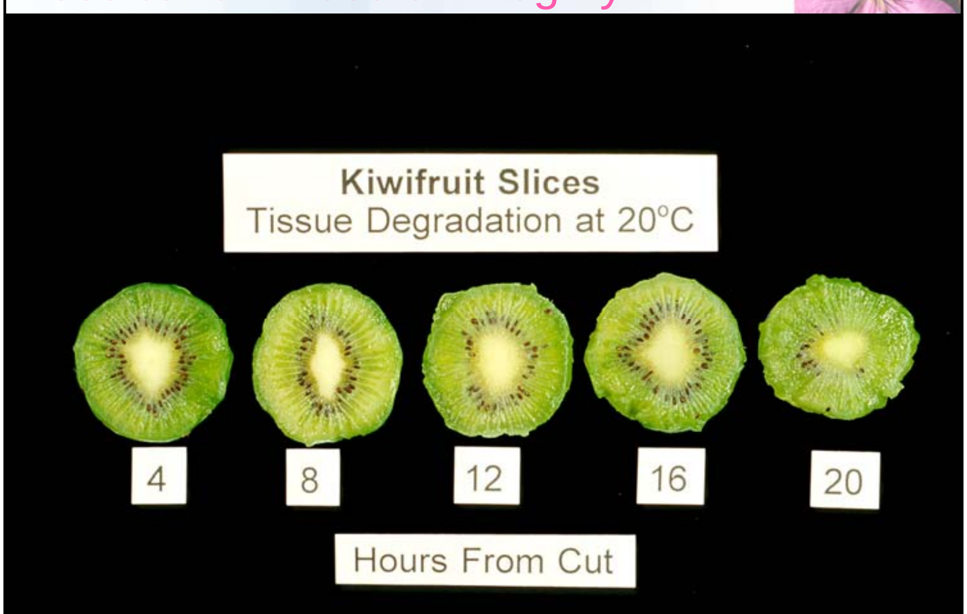
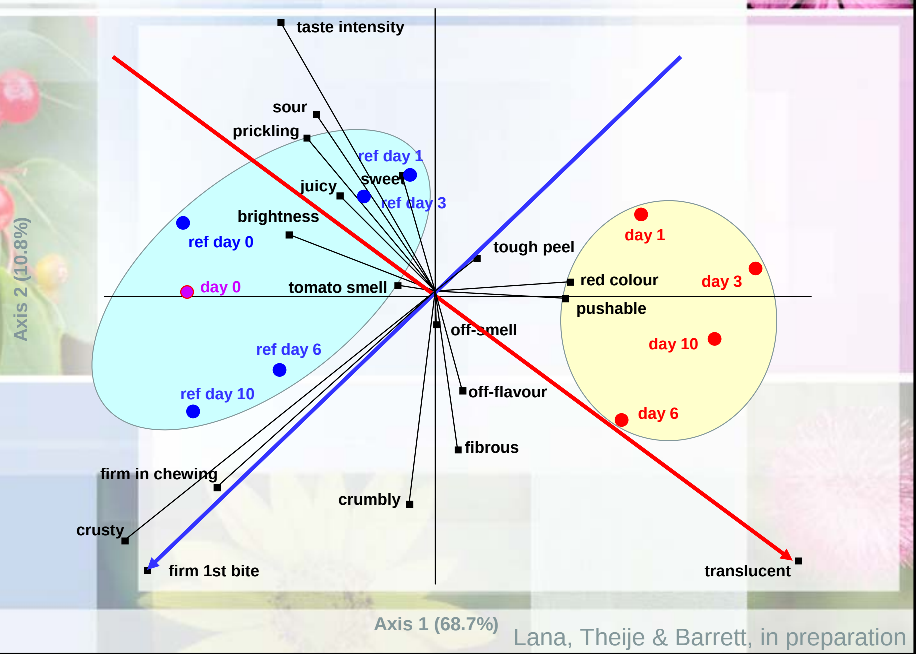



Photo courtesy of Adel Kader.

## Fresh cut sliced tomatoes – sensory differences




Lana, Theije & Barrett, in preparation

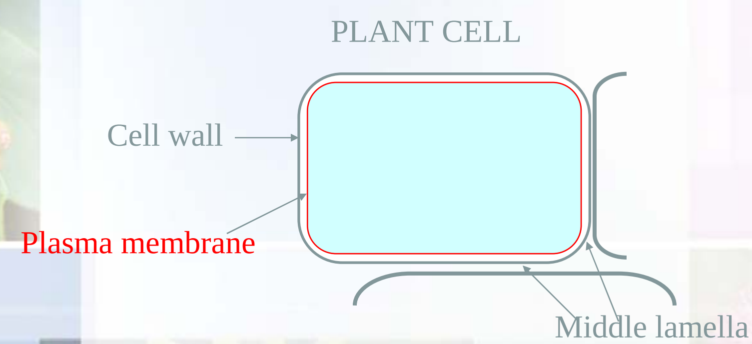
## Preservation of Textural Integrity

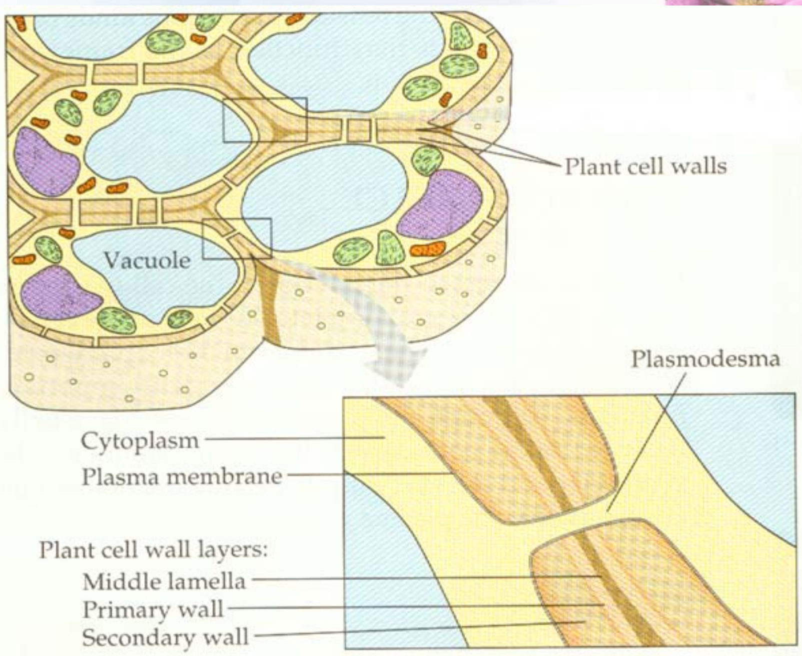
- **Genetic background**
- **Morphology, cell wall and middle lamella structure**
- **Cell turgor**
- **Water content**
- **Biochemical factors, enzyme activity**

## TEXTURAL PROPERTIES
## (firmness: viscoelasticity, turgor)

↕

## STRUCTURAL COMPONENTS
## (cell wall, middle lamella, plasma membrane)





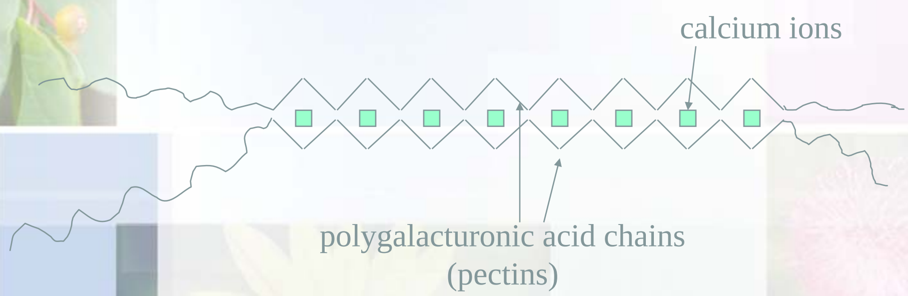

## Effect of Calcium on Texture

- Calcium - forms ionic bonds between pectin molecules with negative charge – Firmness!
- Pectinesterase cleaves methyl esters to form more free carboxylic acid groups allowing more Ca2+ to bind, creating stronger walls.
- Calcium ions also stabilize cell membranes, which may have an effect on turgor pressure, membrane permeability and integrity.

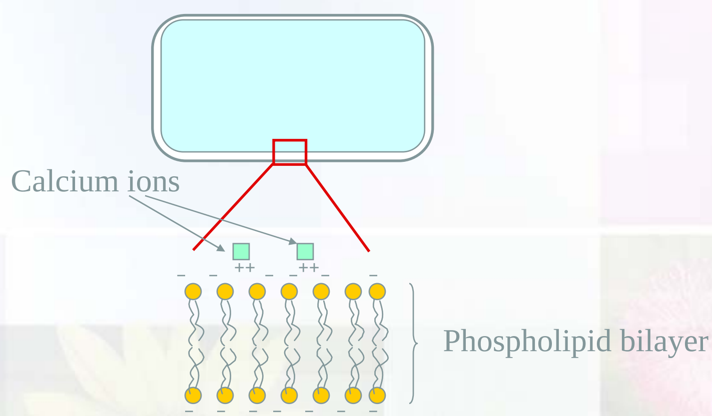
$$\text{—COO}^{-}\ \ Ca^{2+}\ \ {}^{-}\text{OOC—}$$

$$\text{—COOCH}_3\ \ \text{CH}_3\text{OOC—}$$

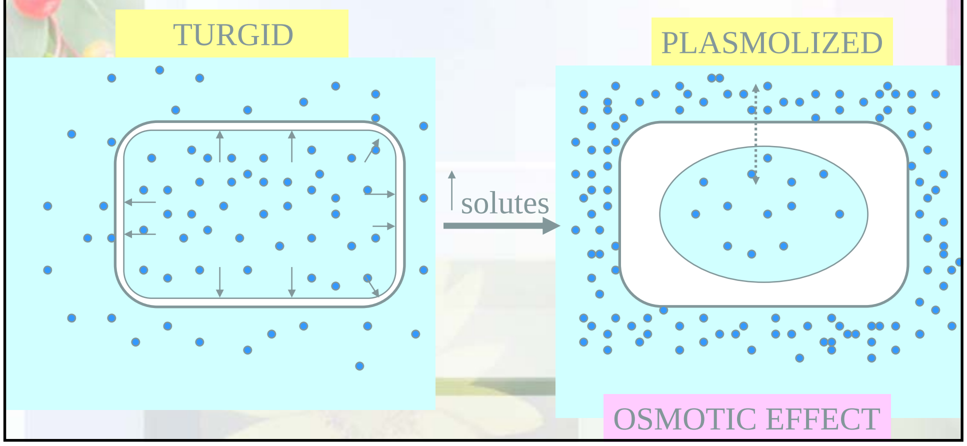
- Calcium interaction with cell walls and middle lamella: "Egg-box" model




**Calcium can also interact with cell membranes and affect turgor pressure**



## Turgor pressure is a function of the osmotic pressure in the tissue




## Use of Calcium in Fresh-cut

- Concentrations typically used ~ 0.5-1.0%
- Must be labeled
- May be used in combination with low temperature blanching for PME activation
- Either CaCl2 or calcium lactate may be used


Thank you!