In the name of God

It is estimated that about <u>one-third</u> of the fresh produce harvested worldwide is lost at some point between harvest and consumption.

According to the UN Food and Agriculture Organization (FAO), the annual world production of fruits and vegetables is about ~ 1,500,000,000 tons!

That means an average loss of ~ 500,000, 000 tons of produce each year!

Postharvest Losses in Developing Countries Often Exceed 50% of the Harvested Crop




First, a few basic principles:

1. **Fresh fruits, vegetables and flowers are living tissues that are subject to continuous changes after harvest!**

Some of these changes are desirable, but most are not wanted.

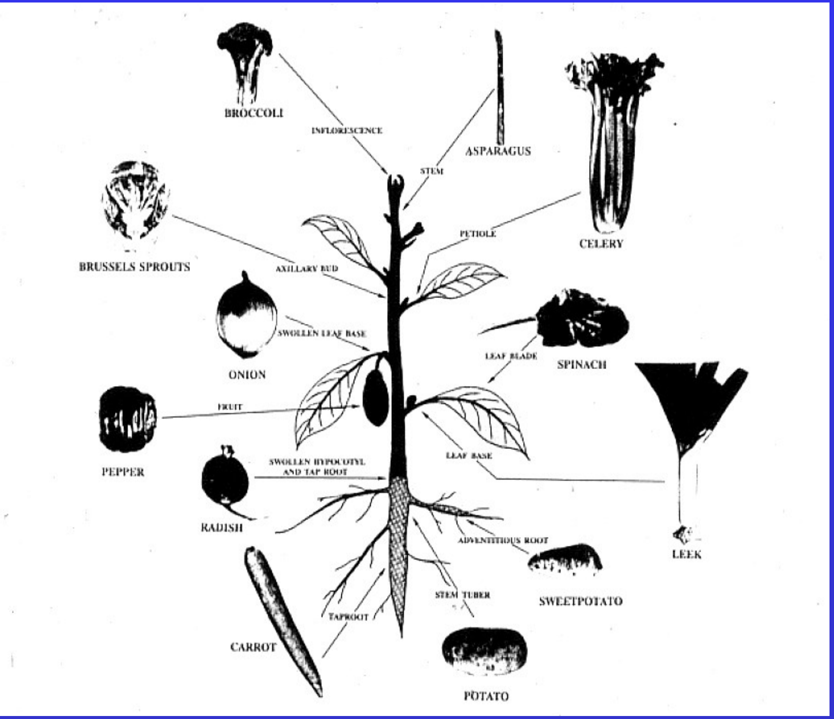
The main goal of postharvest research is to slow these changes as much as necessary.

2. **After harvest – fruits and vegetables are detached from the mother plant and do not ‘enjoy’ anymore from continuous supply of water and nutrients.**

Therefore, after harvest, fruit and vegetables depend on their own carbon and water reserves and become perishable – they loose water and dry matter!

3. **Fresh horticultural crops are diverse in morphological structure (roots, stems, leaves, flowers, fruit, etc.), in composition, and general physiology.**

Therefore, optimal postharvest requirements vary among commodities!



Major Operations in the Horticultural Chain

PRODUCTION

HARVEST

TREATMENT

PACKAGING

TRANSPORT

STORAGE

DISTRIBUTION

MARKETING

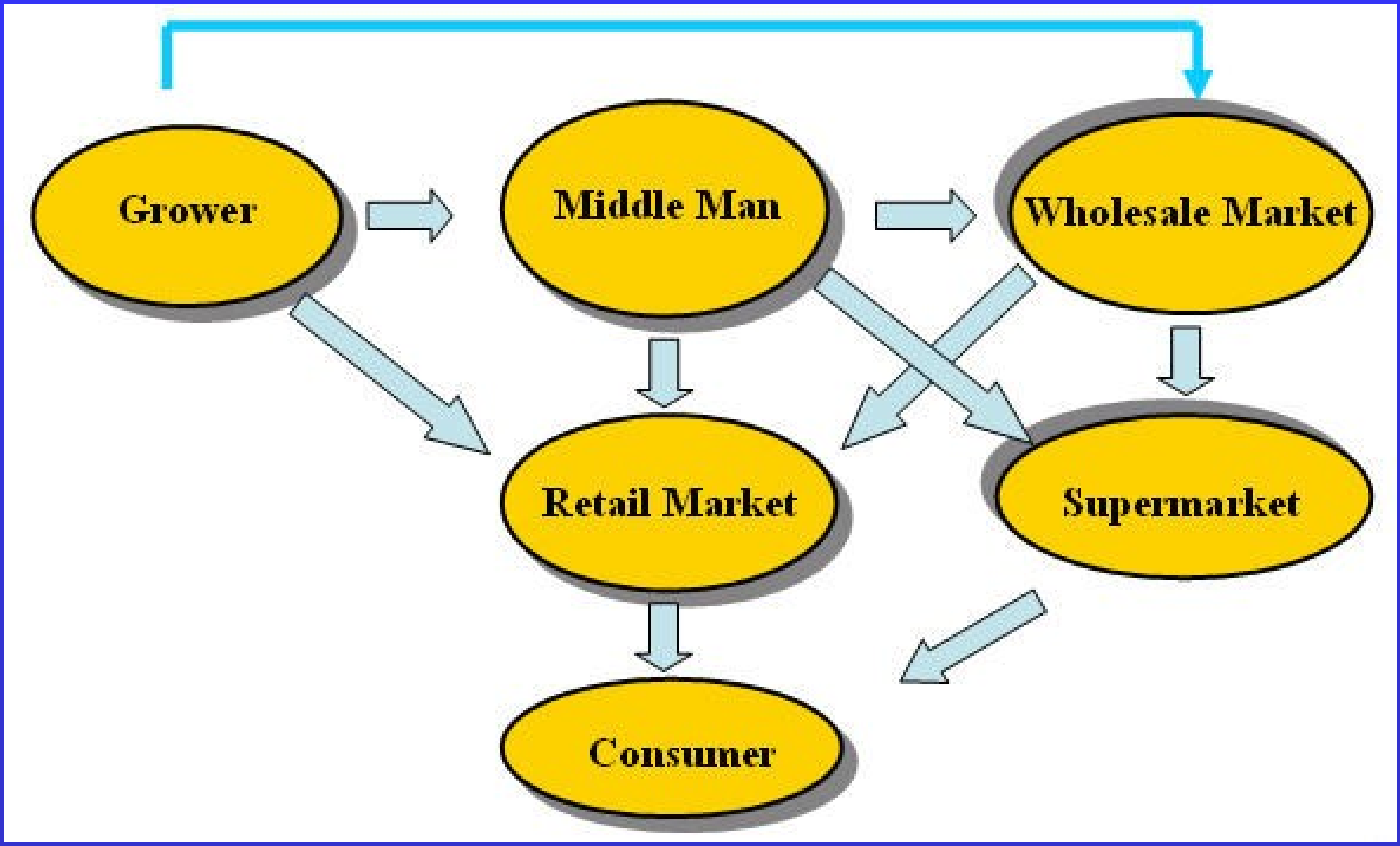
The aim: handle properly and to minimize the risk of contamination to assure safety and quality of produce.

Quality cannot be improved
After harvest

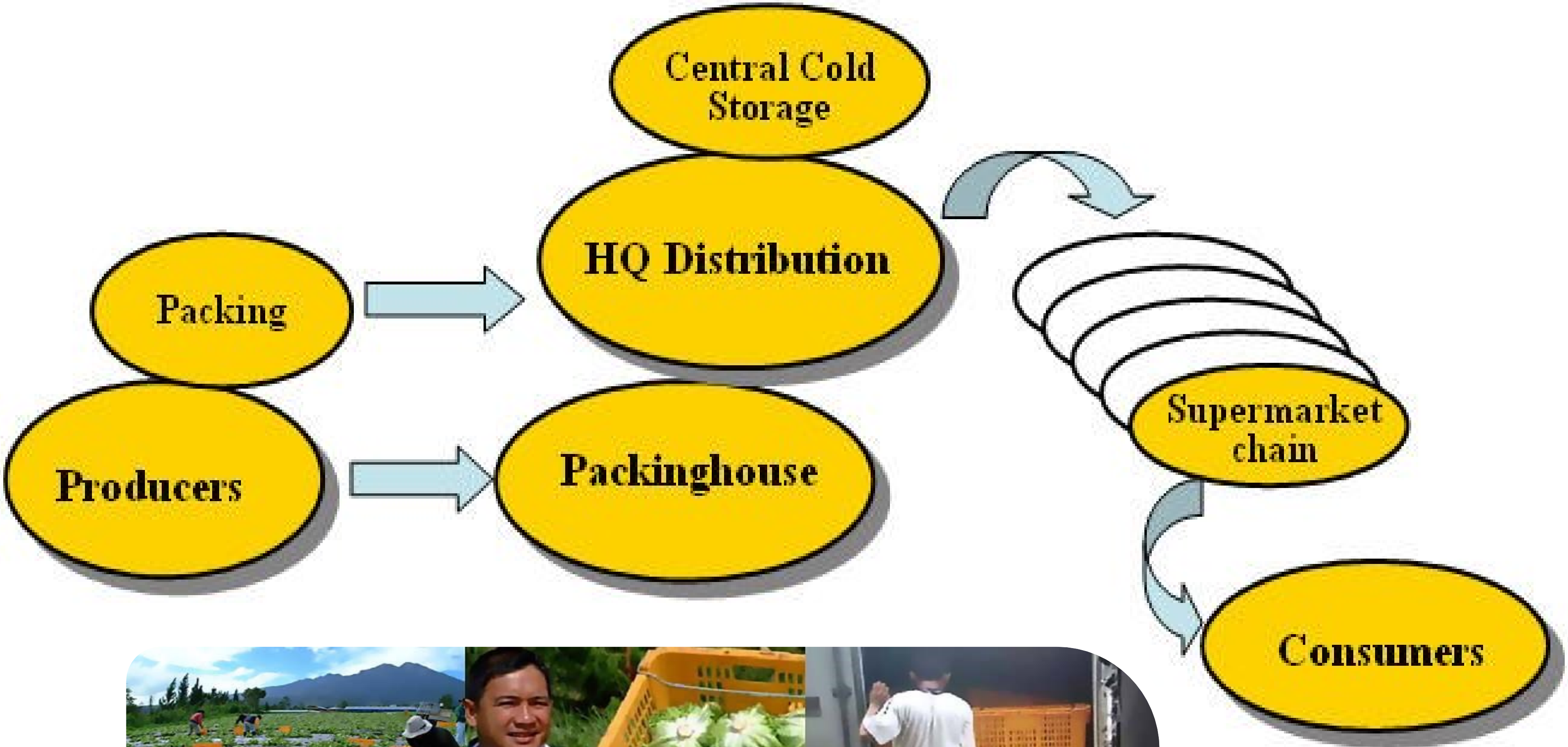
Key Objectives of Horticultural Chain Management

- Reduce losses
- Maintain quality
- Assure safety
- Improve efficiency
- Ensure that consumer and market demand for safe fruits and vegetables can be met

Key Stakeholders in Traditional Horticultural Supply Chains



Key Stakeholders in Modern Value Chains



Good Packaging and proper handling are critical in minimising quality loss

Containers must have smooth surfaces to **avoid mechanical damage** during transportation

- Packaging and other containers used must be repaired if produce damage is to be avoided

What is Quality?

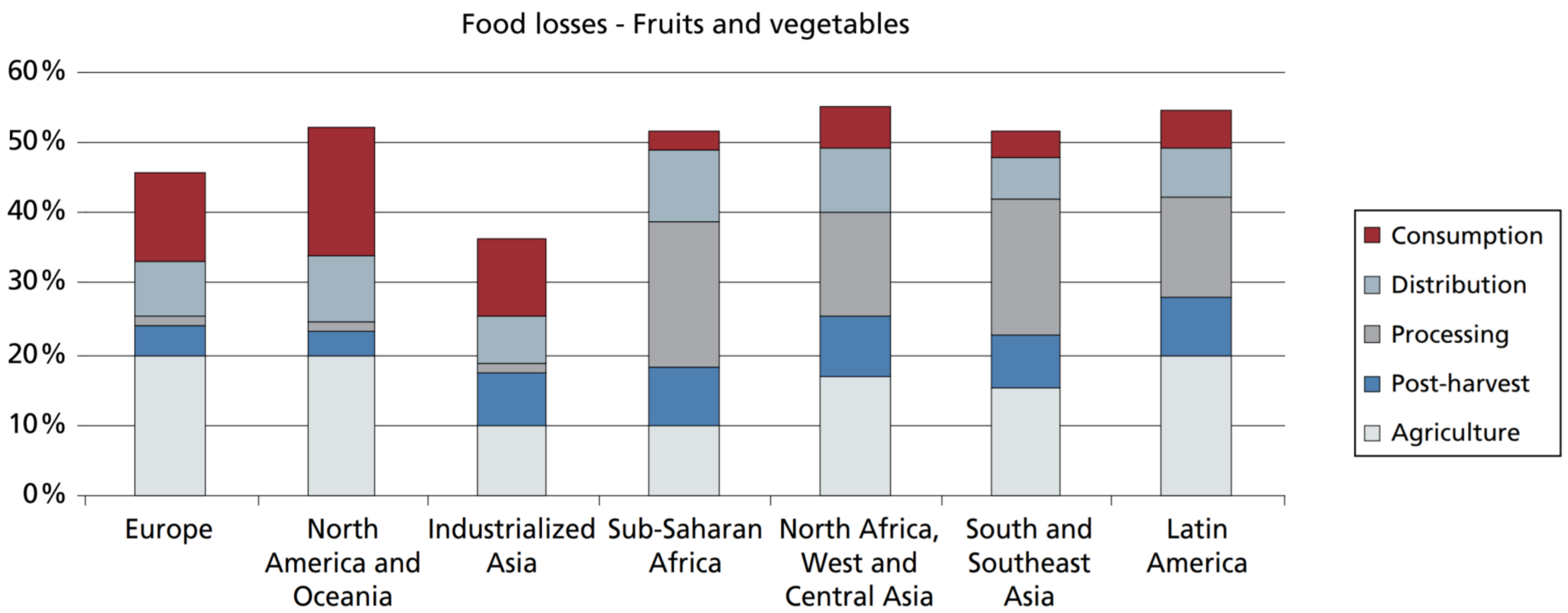
- A combination of attributes, properties or characteristics that give a commodity value in terms of its intended use.

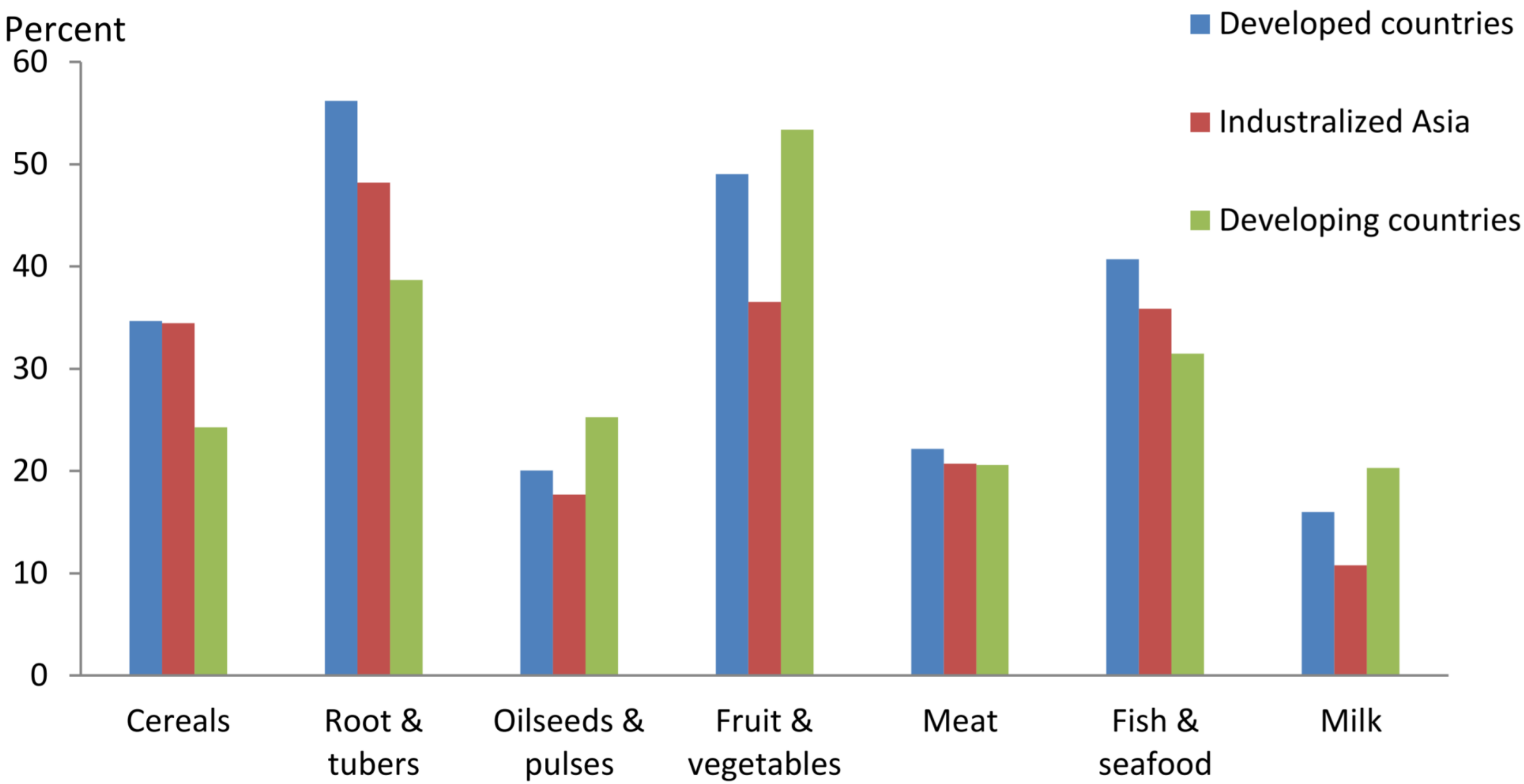
Factors that Contribute to Quality

- Appearance
  - Size, shape, color, gloss, freedom from defects
- Texture
  - Feel in the hand
    - Firmness, softness
  - Feel in the mouth
    - Juiciness, crispiness, toughness
- Flavour
  - Smell
  - Taste
    - Sweetness, sourness, astringency, bitterness
- Nutrition
  - Vitamin, mineral, lipid, protein, carbohydrate, fibre, phytonutrients

Food Safety

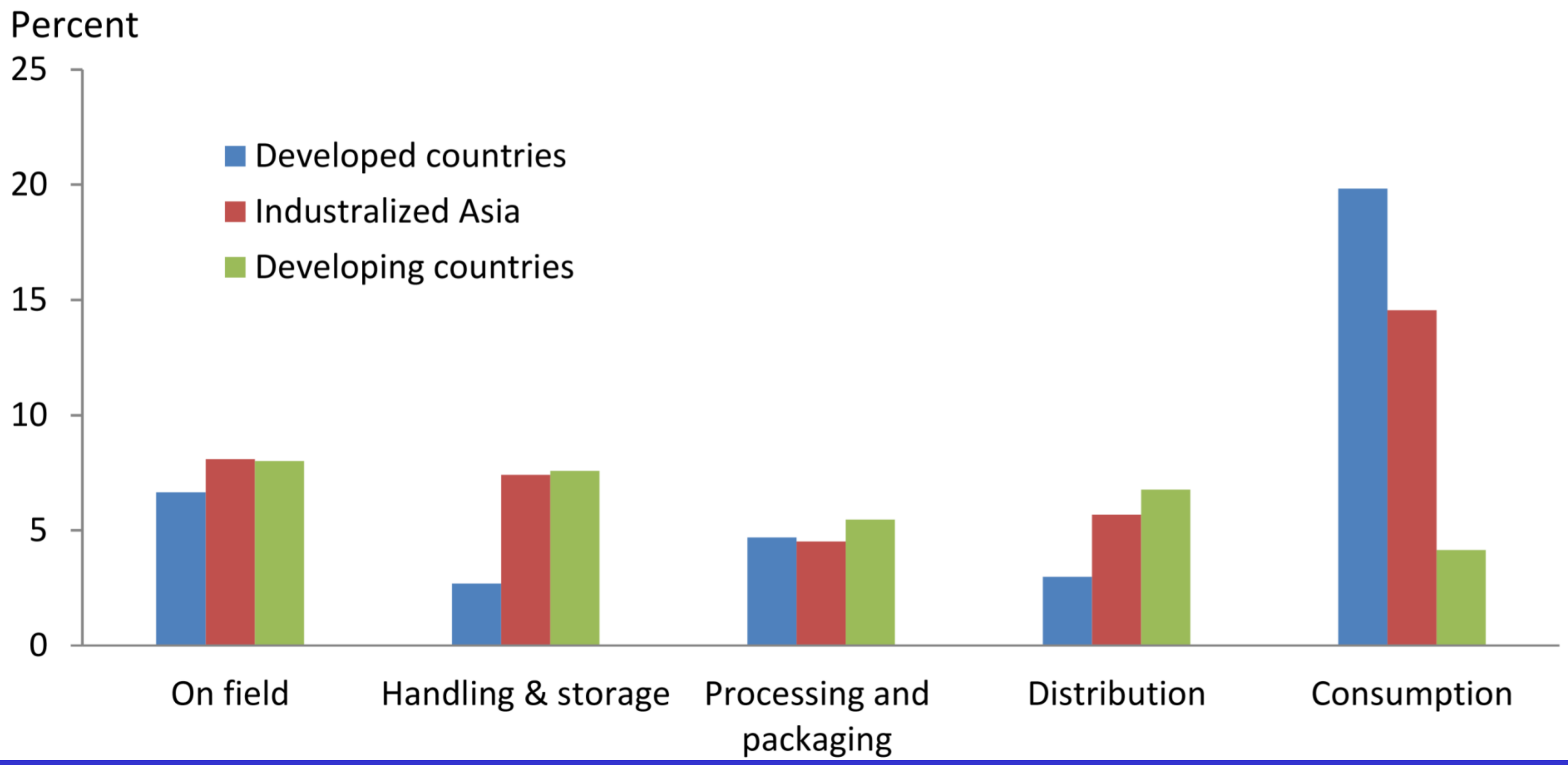
Fresh Produce May Look Good
But a key question is : "**Is it Safe to Eat?**"

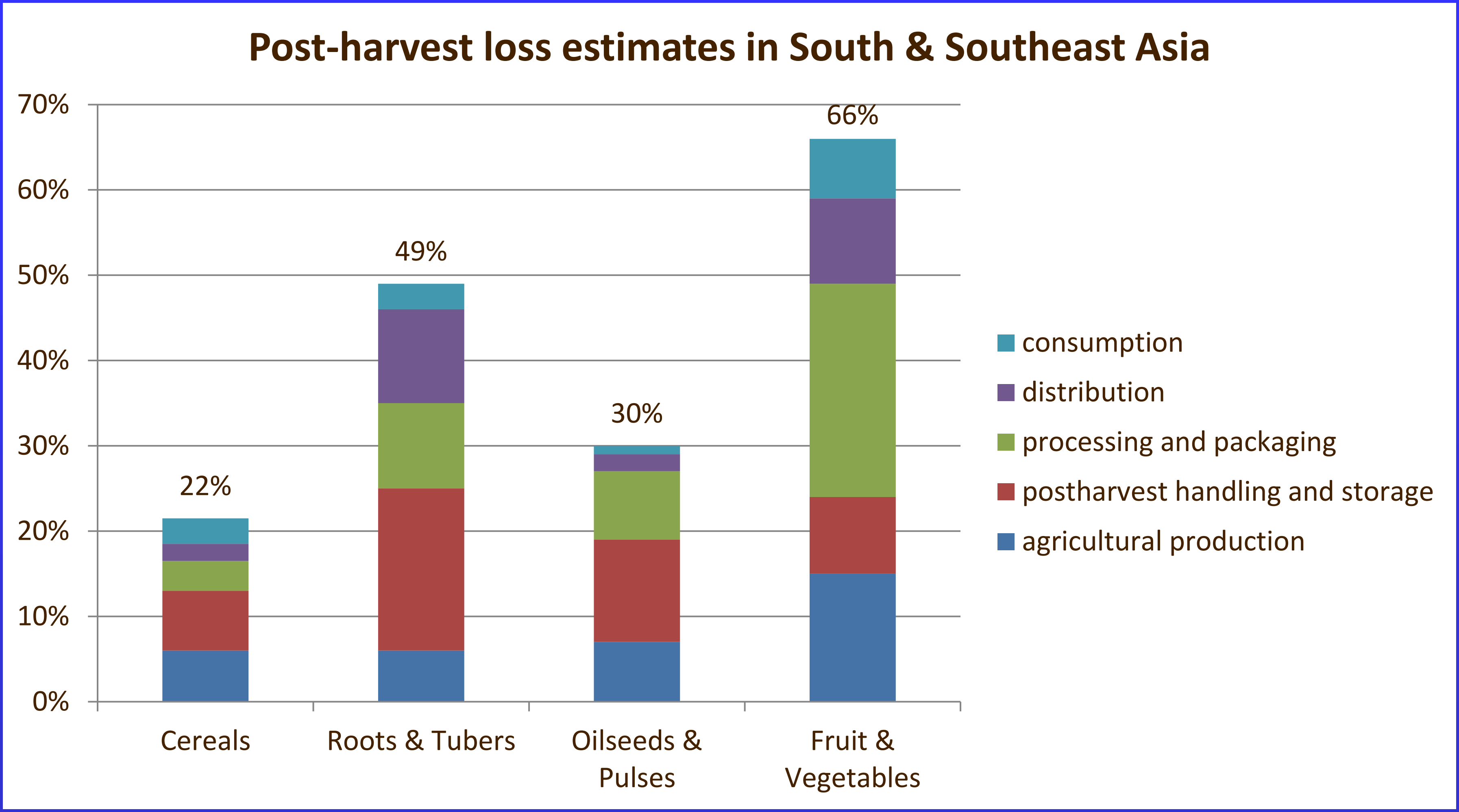

Food losses - Fruits and vegetables
60 %
50 %
40 %
30 %
20 %
10 %
0 %
Europe
North America and Oceania
Industrialized Asia
Sub-Saharan Africa
North Africa, West and Central Asia
South and Southeast Asia
Latin America
Consumption
Distribution
Processing
Post-harvest
Agriculture



Food losses vary by commodity across countries

Food losses vary by the stage of supply chain across countries




Post-harvest loss estimates in South & Southeast Asia
70%
60%
50%
40%
30%
20%
10%
0%
22%
49%
30%
66%
Cereals
Roots & Tubers
Oilseeds & Pulses
Fruit & Vegetables
consumption
distribution
processing and packaging
postharvest handling and storage
agricultural production

Postharvest loss:

Is defined as any change in the quality

(nutrient/caloric composition, the acceptability, and the edibility of a product)

These losses are generally more common in developed countries

or quantity of the product after harvest that decreases its value.

Loss of quantity is more common in developing countries

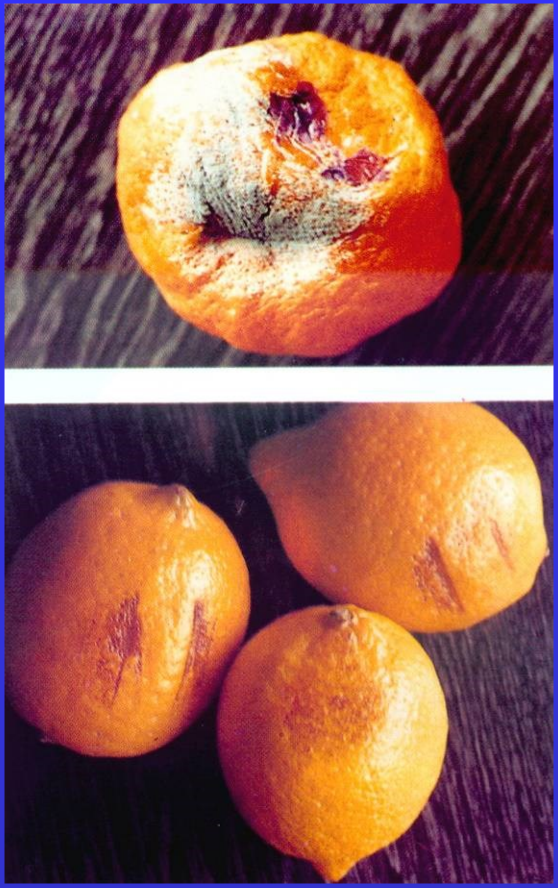
The losses may range from slight defects to total loss of the produce!

Small defects (rind breakdown)

Total loss (sour rot)

Losses during harvest

Pressure damage



Mechanical injury

Spliting

WOUNDING BY THE STEMS

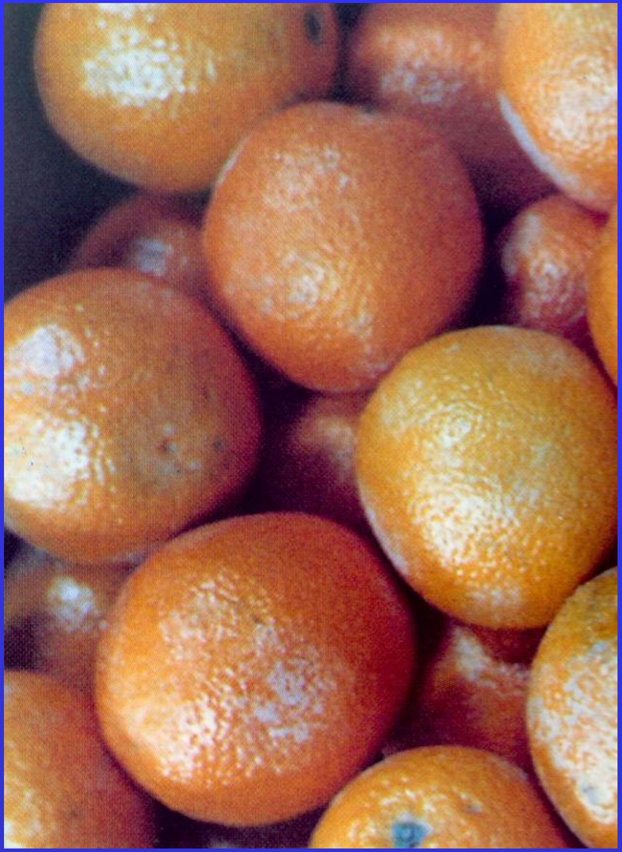
MECHANICAL DAMAGE

BIN DAMAGE

Losses at the packinghouse

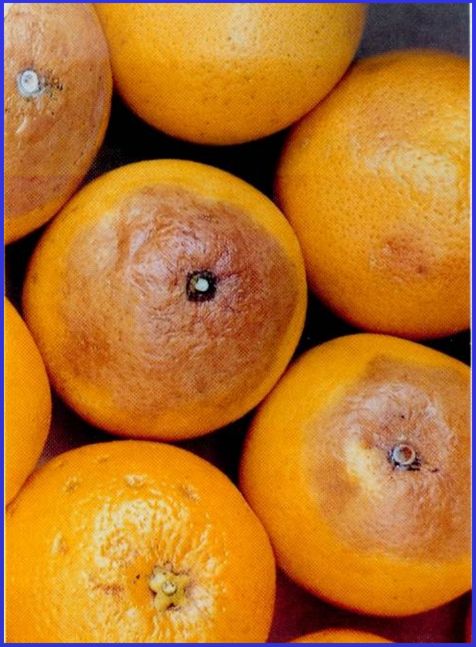
Chemical spray injuries

Wax damage

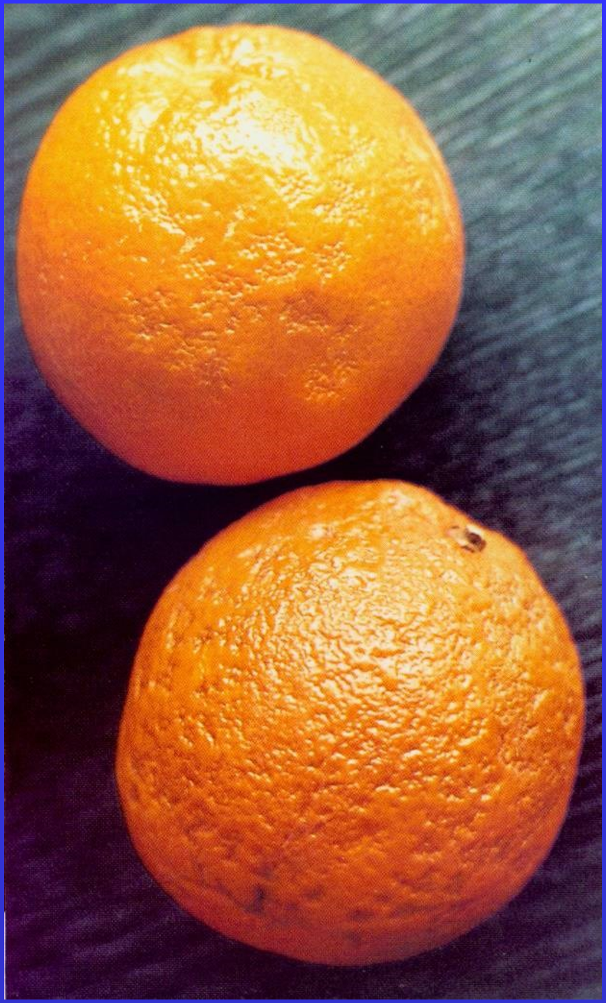


Losses during Storage

Decay

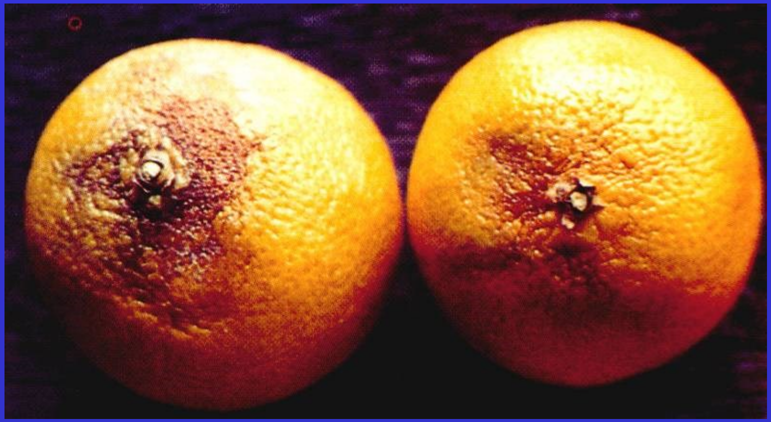


Rind breakdown



Chilling injuries

Stem-end Rind breakdown



CHILLING INJURIES

CHILLING INJURIES

Biological Factors Involved in Deterioration

- Respiration
- Ethylene Production
- Compositional Changes
- Growth and Development
- Transpiration or Water Loss
- Physiological Breakdown
- Physical Damage
- Pathological Breakdown

Environmental Factors Influencing Deterioration

a. Temperature
b. Relative Humidity
c. Atmospheric Composition
d. Ethylene
e. Light

The main causes for postharvest losses during storage are:

1. Physiological deterioration (softening, wilting)
2. Pathological deterioration (decay and rots)

Pathological breakdown

One of the most obvious symptoms of deterioration is growth of pathogens.

Healthy fruit are mostly resistant to pathogens, but senesced and damaged fruit become susceptible to infection.

* Infection by pathogens became a very serious problem in postharvest handling in recent years, since health authorities consistently reduced the permitted residue limits (MRL's) for chemical fungicides.

The major postharvest diseases are caused by several types of fungi:

Alternaria

Botrytis

Diplodia

Penicillium

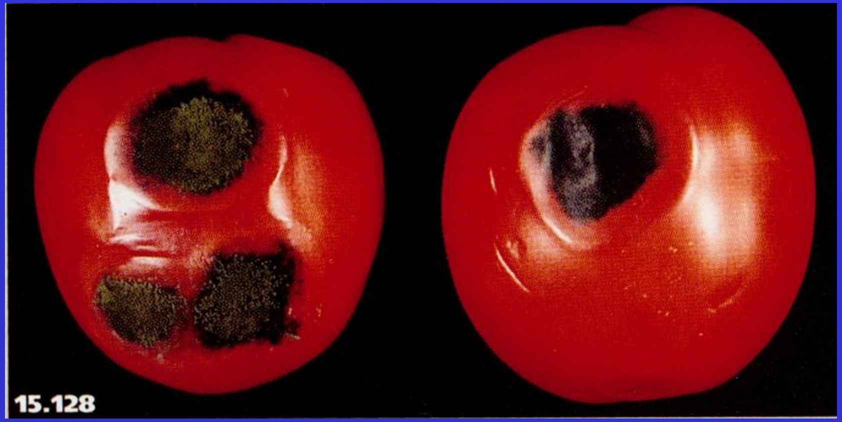
Phytophthora

Rhizopus

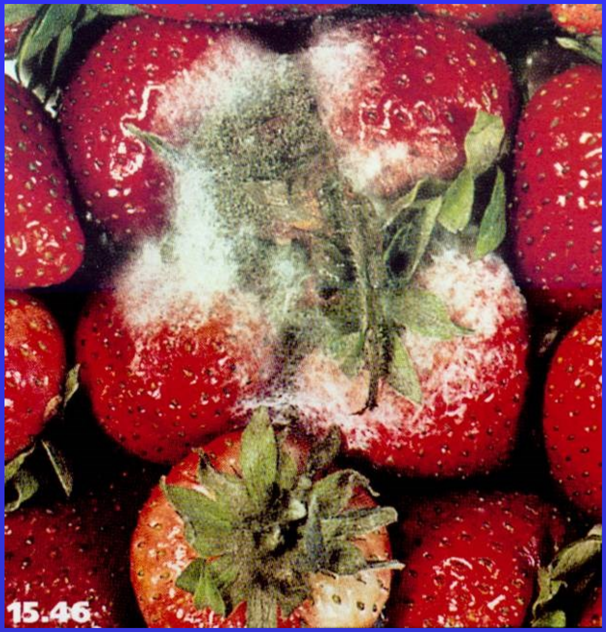
Geotrichum

Colletotrichum

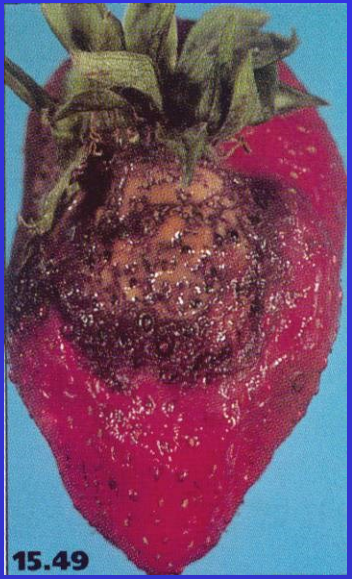
Alternaria rots



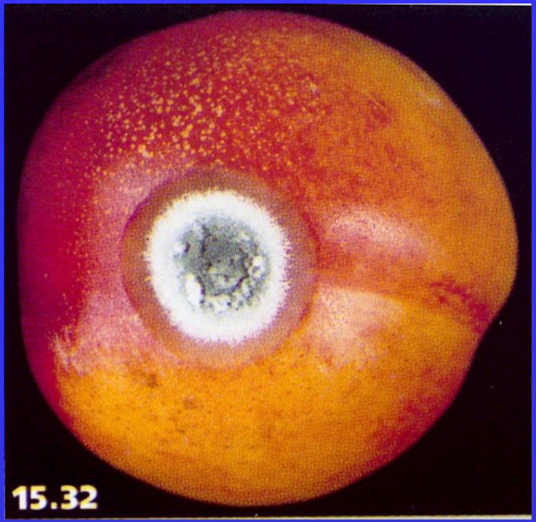
Botrytis rots

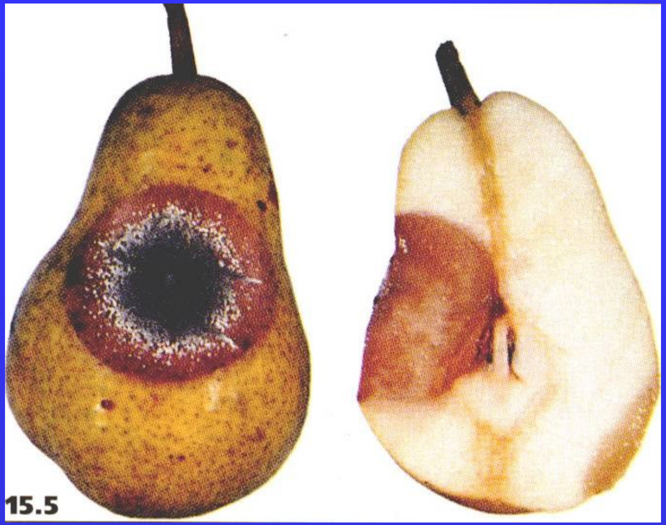


Colletotrichum rots



Penicillium rots





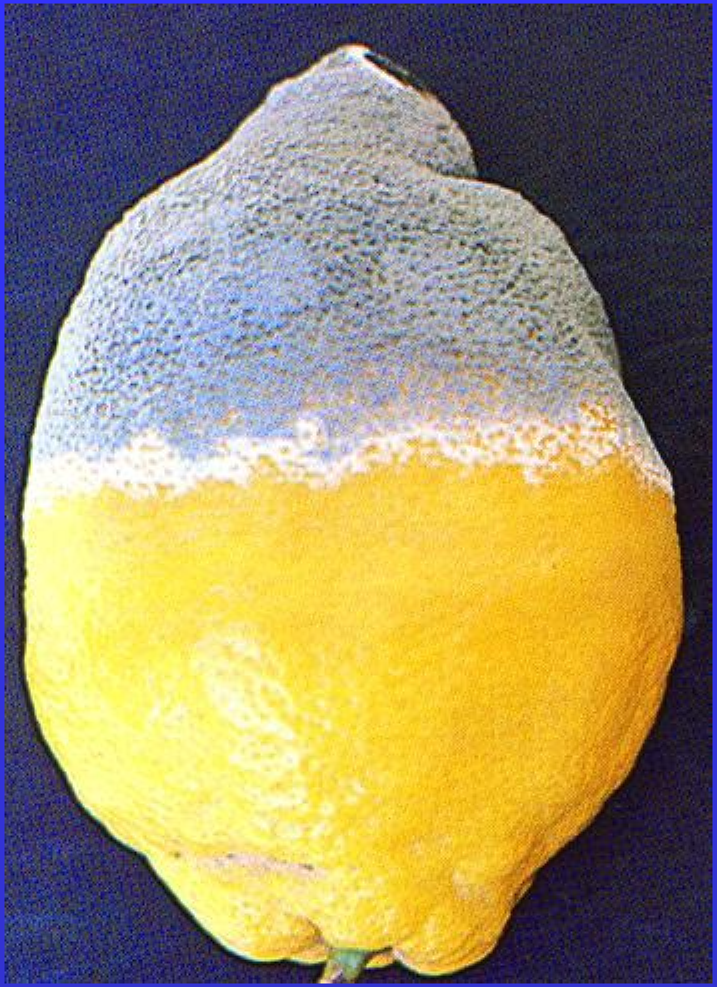
Green and blue mold – Penicillium spp.

Green mold

- *Penicillium digitatum* (green mould)
- *P. italicum* (blue mould)
- Softening of damaged tissue.
- White fungal growth, which progressively turns blue or green as spores develop.

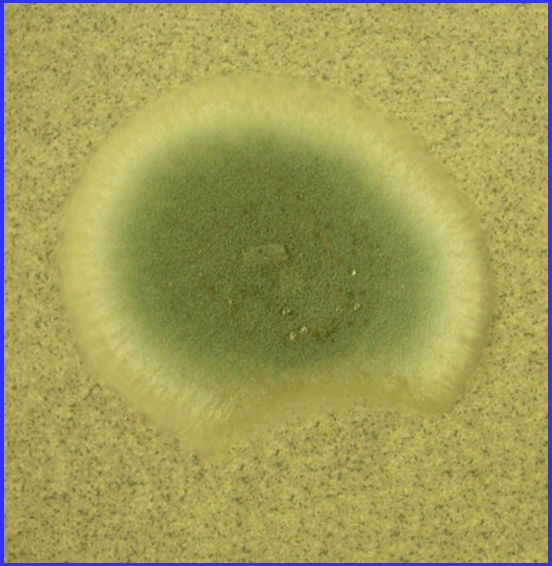
Green and blue mold – Penicillium spp.

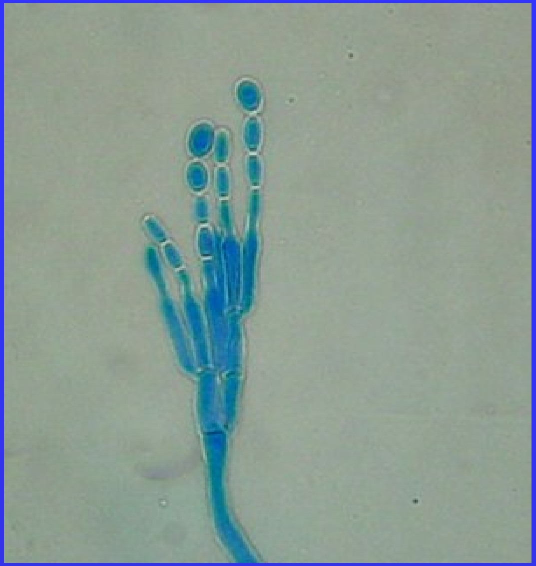
- Infections develop from damaged areas.
- The growth of mould increases with storage
- Optimum temperatures (20-27^{0}C).
- Late season fruit more susceptible.
- Damaged rind is more susceptible.



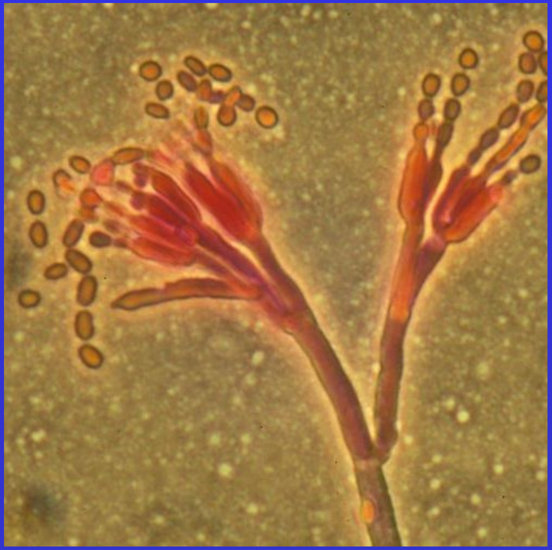
Blue mold

Penicillium digitatum



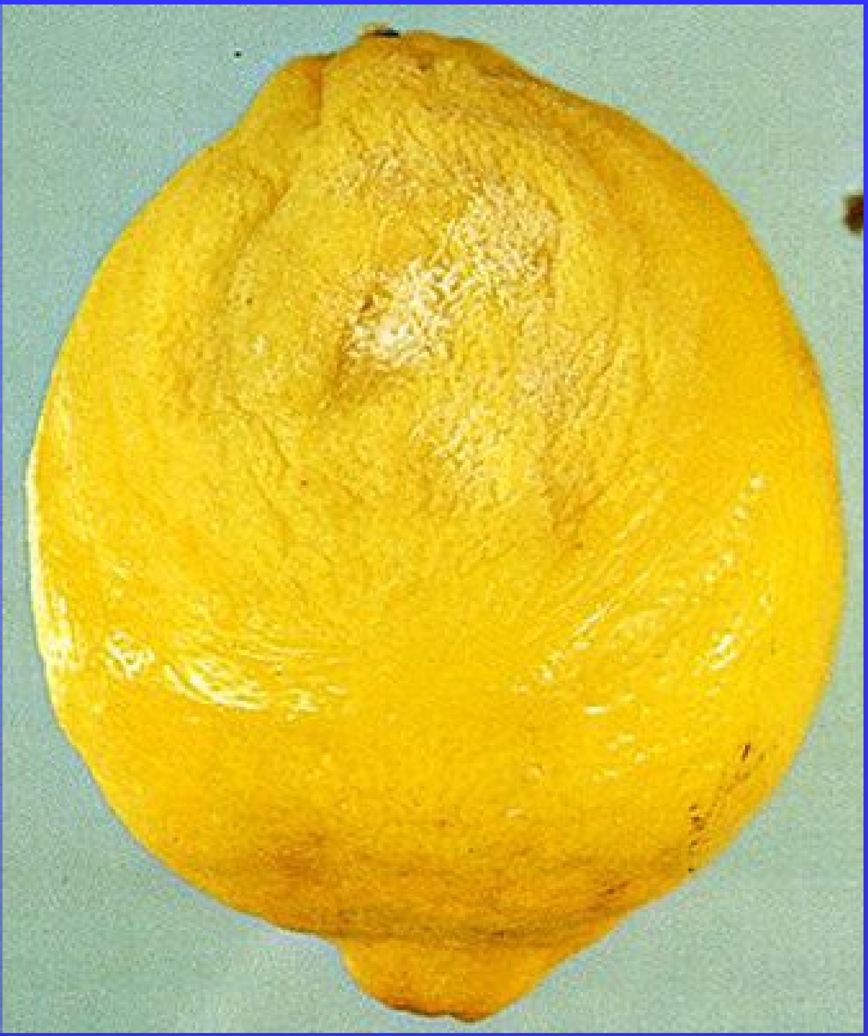


Penicillium digitatum



Penicillium italicum

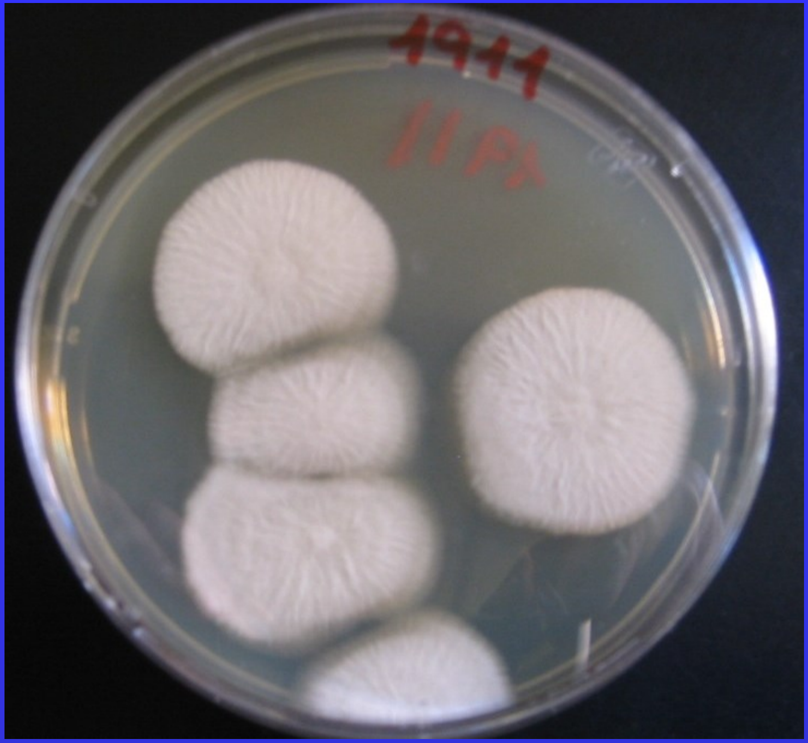
Sour rot - Geotrichum candidum

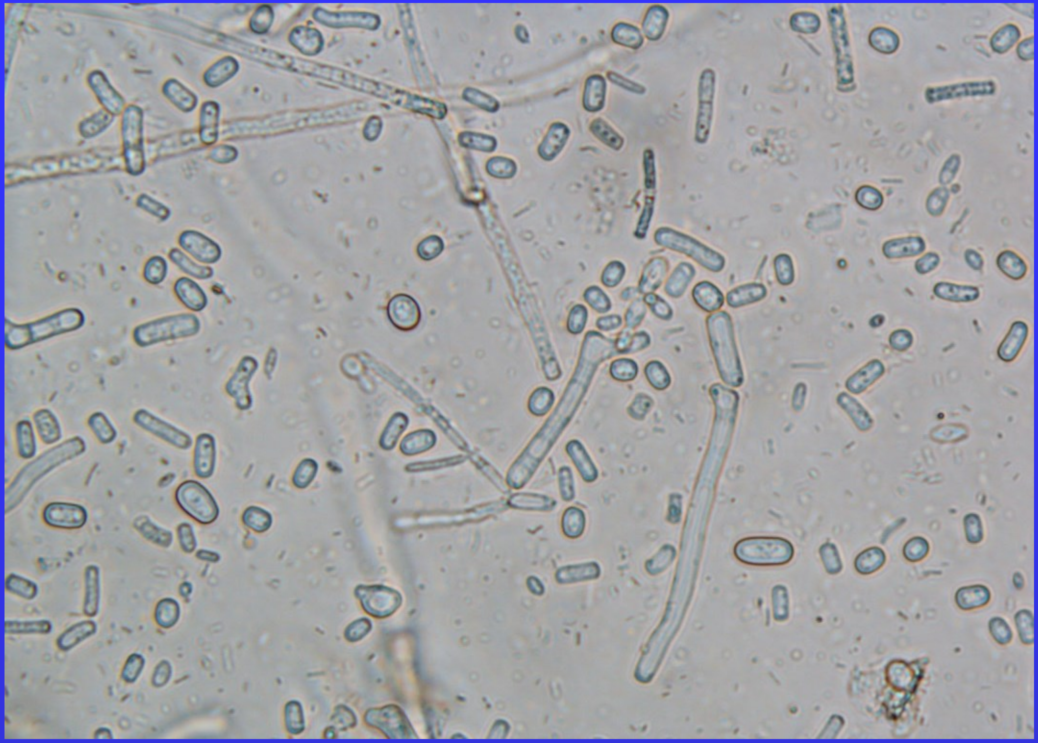


- Very soft, watery decay.
- Distinct margin between decayed and healthy tissue.
- Lesions covered with slimy off-white spores
- Sour odour detectable.

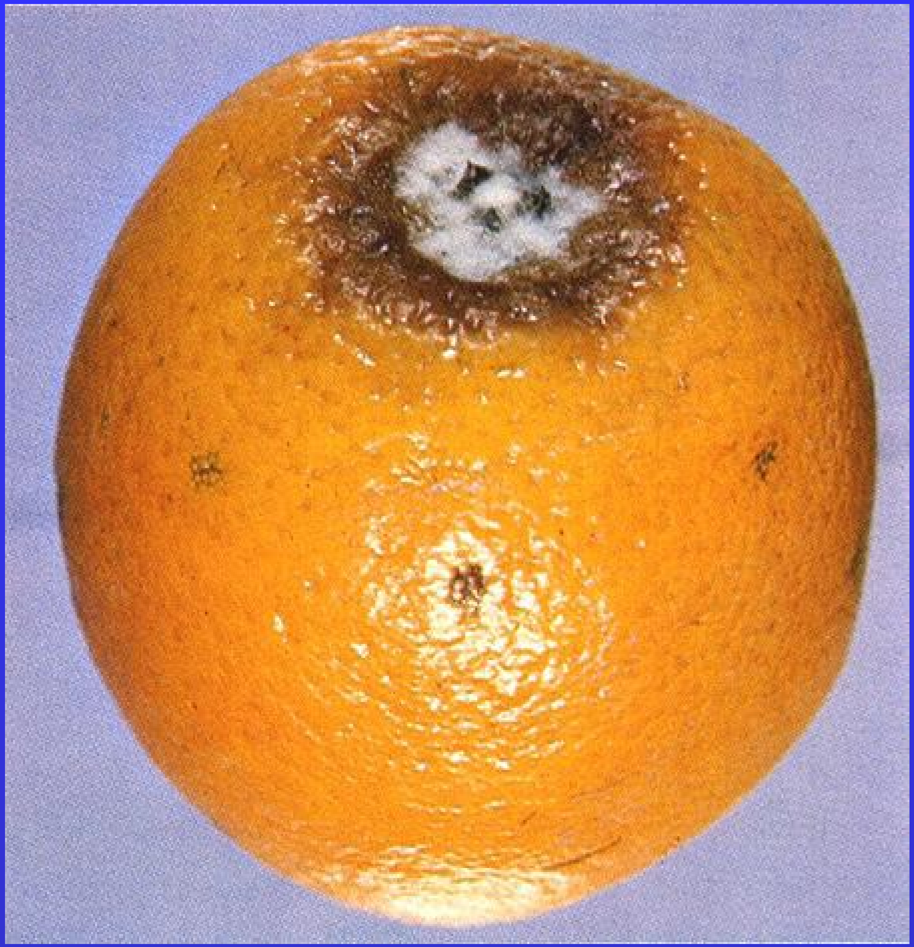
- Prevalent after warm wet areas
- Pathogenic on ‘weak’, wounded, bruised, and split fruit
- Lemons, limes and grape fruits stored for extended periods
- Ripe fruit is more susceptible

Geotrichum candidum





Stem end rot - Lasiodiplodia theobromae

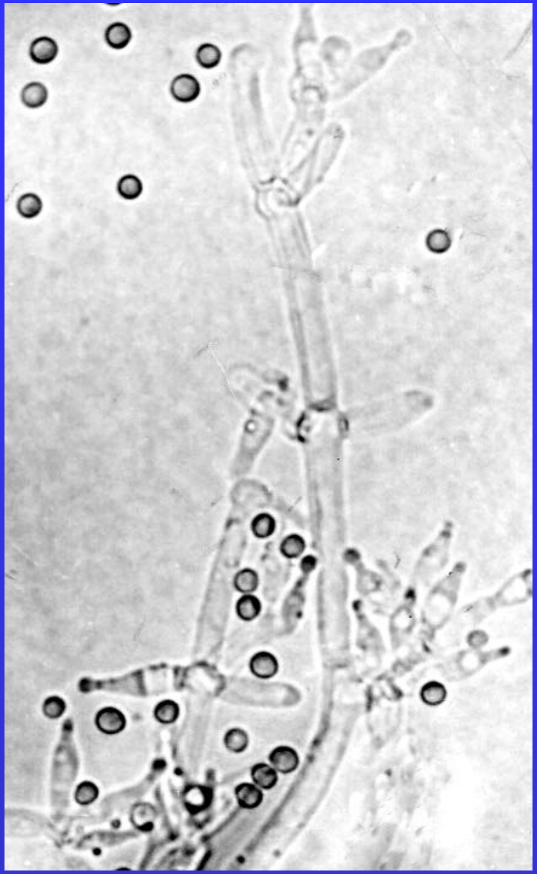


- Softening of tissue around button
- Brown rind
- Rapid decay down the axis of the fruit reaching stylar end

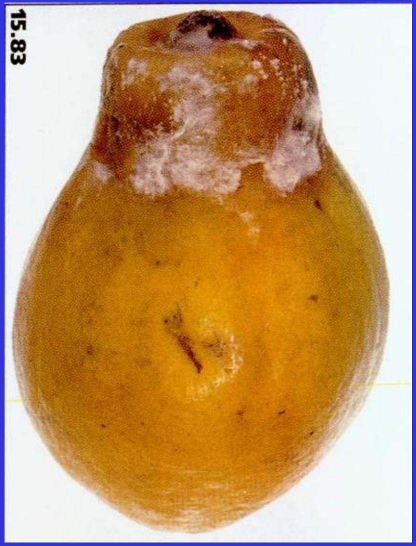
Trichoderma rot - Trichoderma viride

- Peel turns dark brown
- Odour of coconuts
- Yellaow green to dark green sporulation on surface

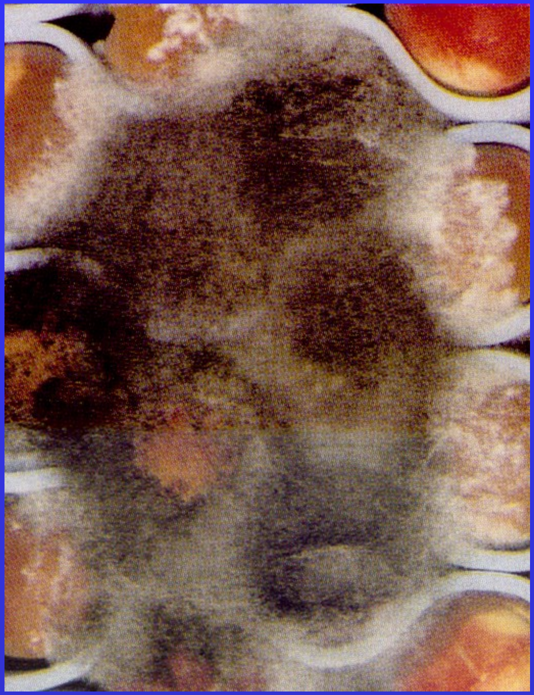
Trichoderma viride



Phytophthora rots



***Rhizophus* rots**



15.133

15.126

There are specific genetic interactions between the host and the pathogen, which govern if the commodity will be resistant or susceptible.

For example, *Penicillium digitatum* attacks only citrus, whereas *Penicillium expansum* can attack apples and pears but not citrus.

The infection process

Fruit and vegetables may be infected in the field while they are still attached to the plant (preharvest infection) or after harvest (postharvest infection).

Preharvest infection – occurs especially on floral parts and during fruit development.
These infections are arrested until the commodity ripens and senesces. Examples are *Colletotrichum, Botrytis* and various stem-end rots.

Postharvest infection – occurs after harvest by penetration through the skin or by invasion through surface wounds. Examples are *Penicillium* and *Rhizophus.*

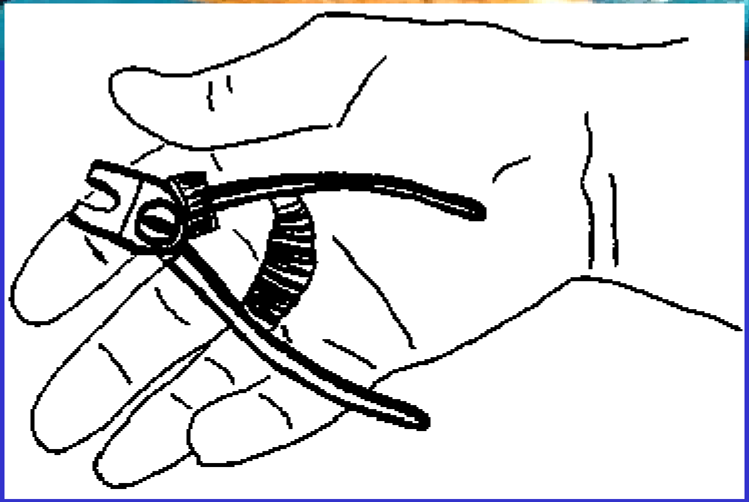
Sources of infection

* At the field or orchard
* Greenhouses
* Harvesting tools
* Boxes, etc.
* Storage facilities
* Markets

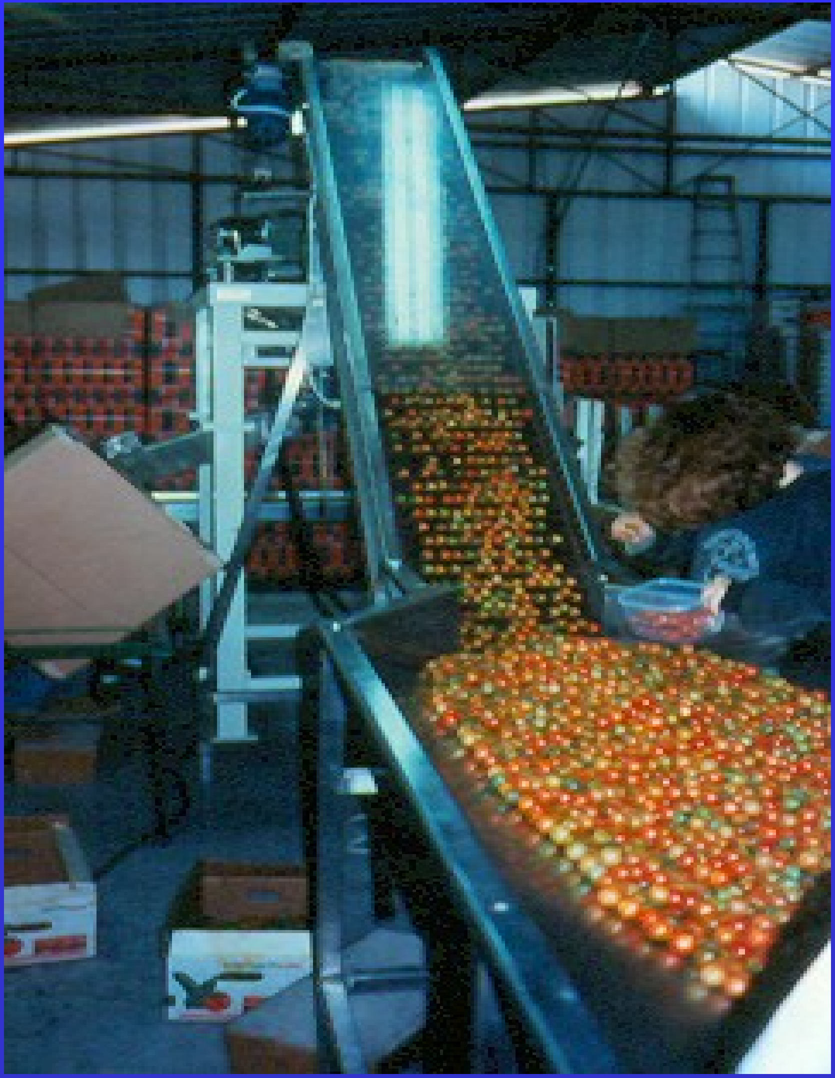
Fields

Greenhouses

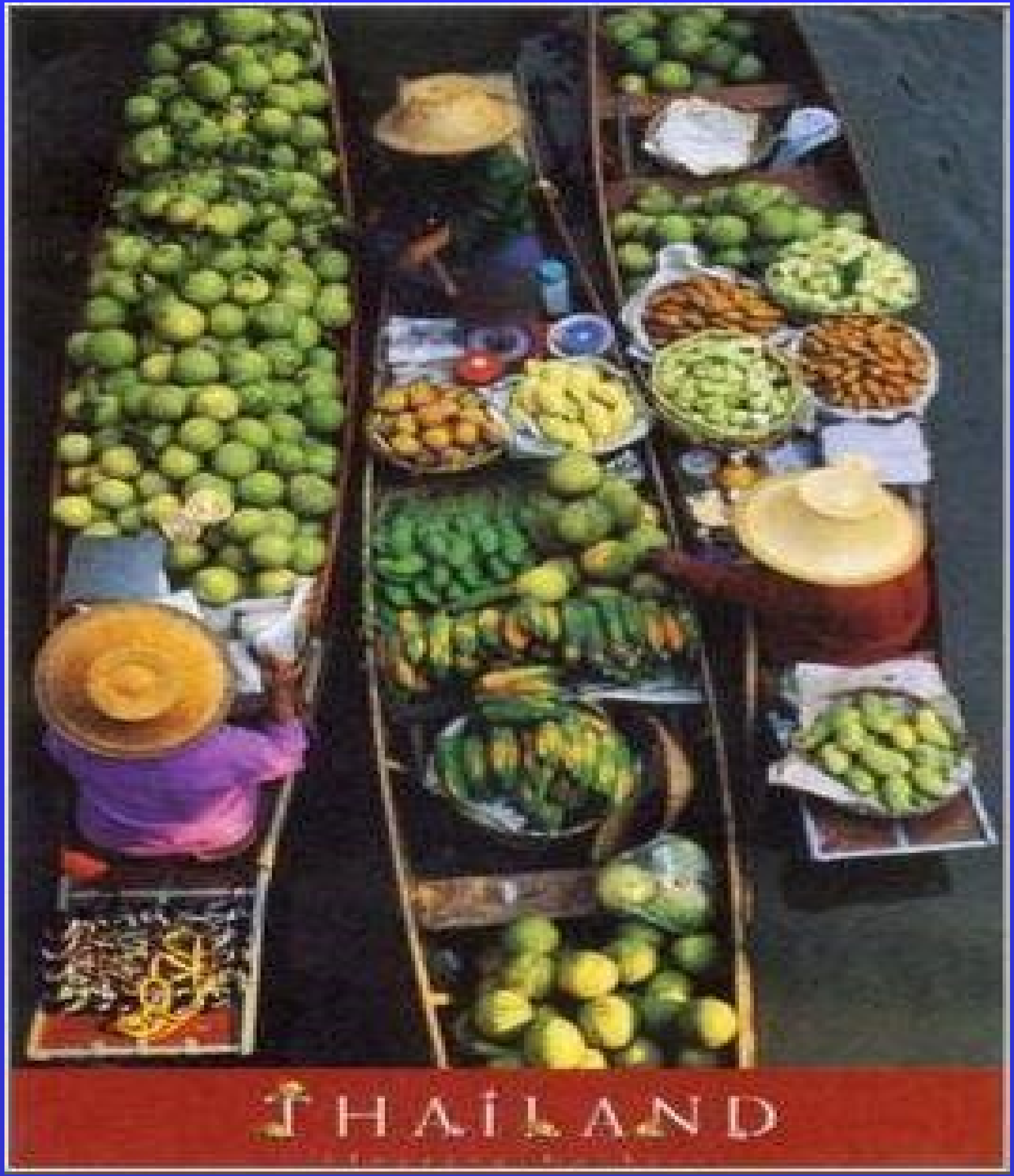
Harvest tools and instruments



Packinghouse facilities



Markets



Factors affecting disease development

* Storage temperature
* Humidity
* Controlled atmosphere
* Produce maturity and defense mechanisms

Temperature

★ Temperature is the most critical environmental factor used to control decay development.

★ Low temperature reduces decay development directly by inhibiting fungus growth and indirectly by maintaining quality and reducing deterioration.

★ Most postharvest pathogens grow best at 20-25ºC. Lower temperatures slows and even may kill the pathogen.

Fruit and vegetables should be cooled as soon as possible to inhibit pathogen growth.

Any delay in cooling after harvest promotes pathogen growth.

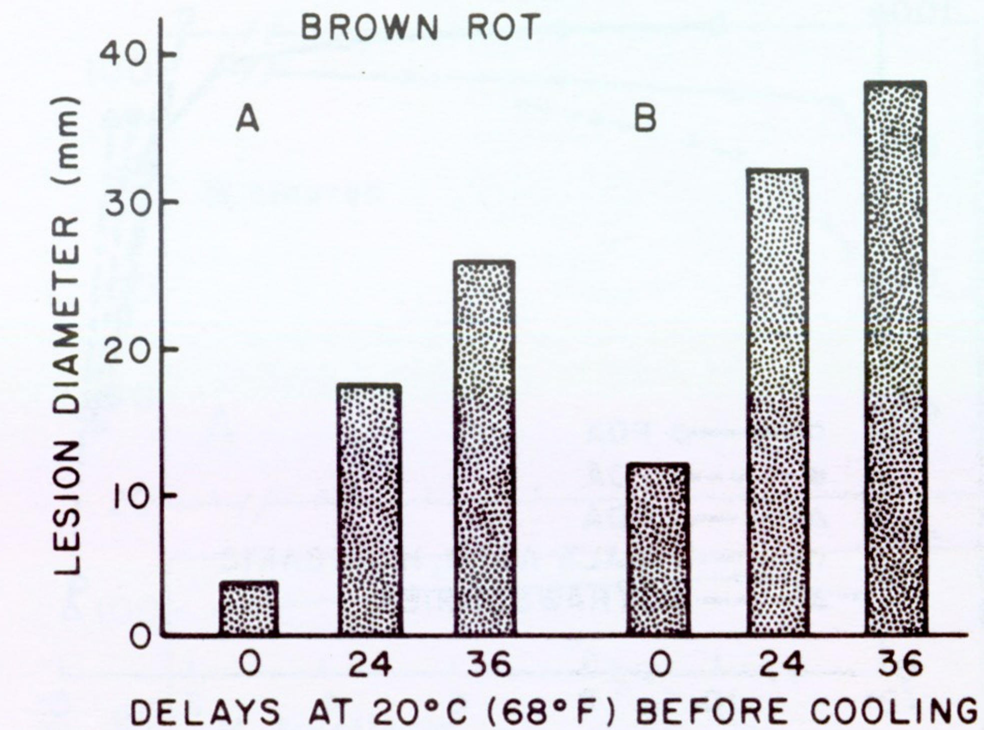
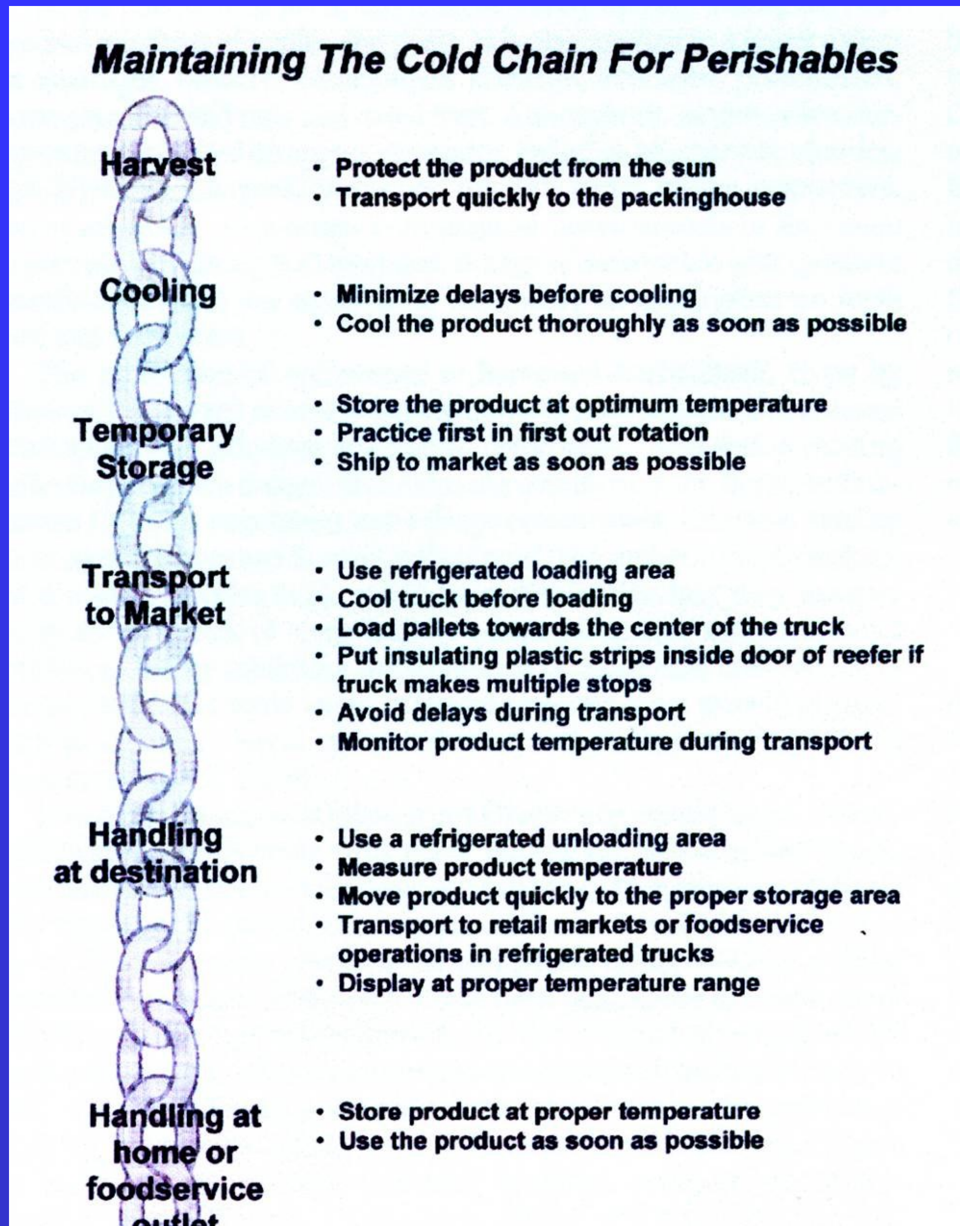


Fig. 14.6. Cooling delays and subsequent rot development. Peaches were stored at 0°C (32°F) immediately or after delays of 24 or 36 hours. Data indicate rot development (A) 3 days and (B) 6 days after removal from cold.

It is important to maintain the "cold chain" to reduce decay throughout the different handling stages



Maintaining The Cold Chain For Perishables

Harvest
- Protect the product from the sun
- Transport quickly to the packinghouse

Cooling
- Minimize delays before cooling
- Cool the product thoroughly as soon as possible

Temporary Storage
- Store the product at optimum temperature
- Practice first in first out rotation
- Ship to market as soon as possible

Transport to Market
- Use refrigerated loading area
- Cool truck before loading
- Load pallets towards the center of the truck
- Put insulating plastic strips inside door of reefer if truck makes multiple stops
- Avoid delays during transport
- Monitor product temperature during transport

Handling at destination
- Use a refrigerated unloading area
- Measure product temperature
- Move product quickly to the proper storage area
- Transport to retail markets or foodservice operations in refrigerated trucks
- Display at proper temperature range

Handling at home or foodservice outlet
- Store product at proper temperature
- Use the product as soon as possible

Humidity

High humidity during storage is required to maintain produce quality and fresh weight.

However, high humidity, and especially water condensation on the fruit surface, also promotes pathogen growth and decay.

Therefore, the optimal humidity should be evaluated specifically for each commodity.

Controlled atmosphere

Controlled atmosphere may directly inhibit pathogen growth or indirectly inhibit decay by delaying ripening and senescence.

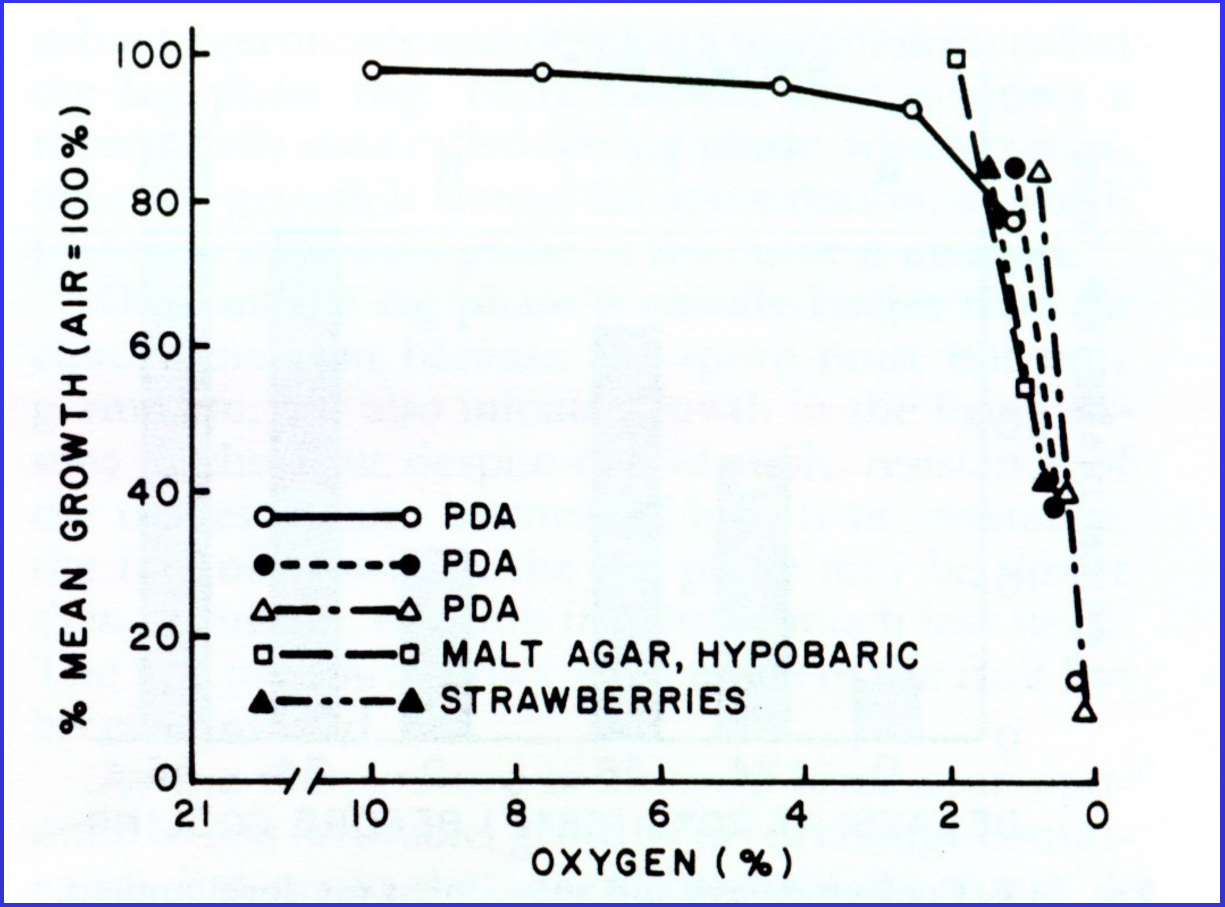
Low O_2 – For many commodities, CA storage includes 2-5% O_2 (lower levels enhance anaerobic respiration).

However, only lower oxygen levels below 1% significantly reduce pathogen growth.

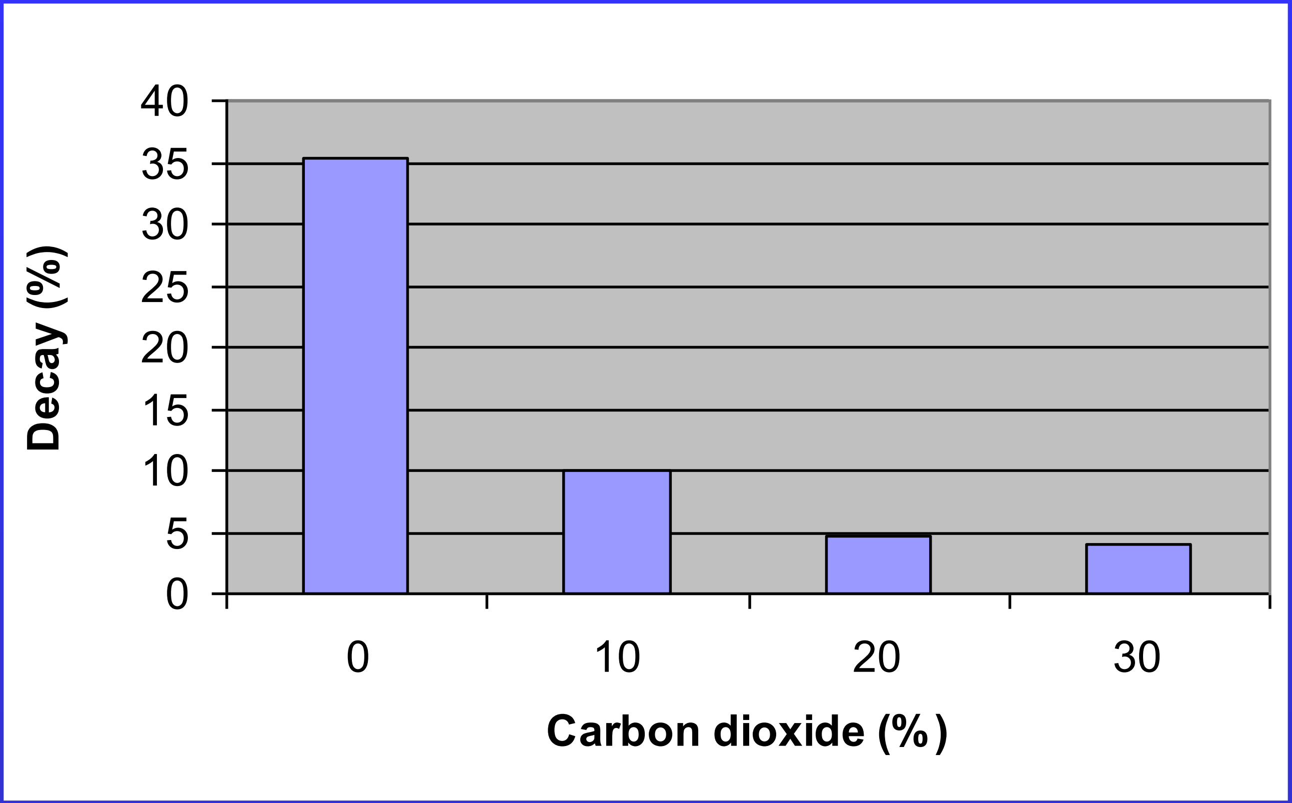
High CO_2 – High CO_2 levels (10-15%) are used in CA storage of some commodities (strawberry, figs, cherry).

These high CO_2 concentrations also inhibit pathogen growth.

Effects of low oxygen on growth of *Botrytis cinerea* in culture



Effects of high CO_2 concentrations on growth of *Botrytis cinerea* in culture



Maturity and natural host defense mechanisms

Young immature fruit are normally resistance to pathogen infections.
However, when the fruit ripens it becomes more susceptible to various diseases.

Natural host pathogen defense mechanisms include toughness of cell walls, production of phytoalexins, induction of pathogenesis-related (PR-proteins), lignification, etc.

Control of postharvest decay

Field treatments

Sanitation: Sanitation in the fields by pruning and removal of dead wood and fallen rotted fruit.

Field sprays: Field treatments with fungicides help protecting against infection in the field.

Careful picking and handling: To avoid mechanical damage, wounds and injuries.

Maintenance of fruit resistance: Treatments with growth regulators, such as gibberellic acid and 2,4-D, delay senescence and maintain fruit resistance.

Sanitation

Careful handling

Chemicals

Control of postharvest decay (continue)

Postharvest treatments

Washing: Washing removes spores and reduces the initial inoculum present on the commodity surface.

Chemical treatments: Postharvest fungicides are currently the most effective method used to reduce decay.

Physical treatments: Hot water (heat) and irradiation may be used for sanitization of produce.

Washing and cleaning

Before

After

Chemical treatments

- Postharvest fungicides are currently the most effective method to reduce decay.
- Chemical fungicides prevent germination of fungal spores and inhibit mycelial growth.
- The problem with chemical treatments is that most fungicides are toxic, and because of health concerns, their use is limited to certain allowed residue uptake levels, whereas others fungicides were totally abounded for postharvest use.

List of some registered postharvest fungicides

Chemical name	Maximum residue limit (MRL)
Calcium hypochlorite	25 ppm
Captan	25 ppm
Imazalil	10 ppm
Sulfur dioxide	10 ppm
Thibendazole	10 ppm