Fruit and Vegetable Storage and Preservation Technologies





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01

Overview of Fruit and Vegetable Storage

Background— Why Storage Matters?

2024 Production: over 2.5 billion tons of fruits & vegetables worldwide.

Postharvest Losses: 20%–40% lost to decay (due to handling, storage, transport, processing gaps)

Storage Technology Delivers:

- Extends shelf life & preserves quality
- Reduces postharvest losses
- Stabilizes supply & prices
- Supports food security & trade



Three Revolutions in Modern Storage Technology

Refrigeration — The First Preservation Revolution

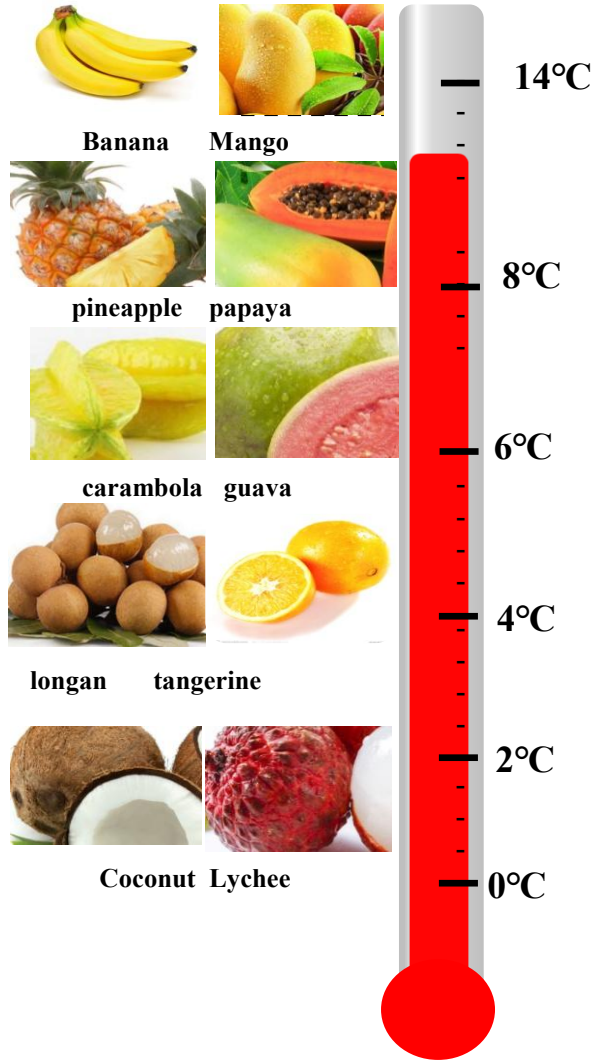
Preservation Principle: Low-temperature refrigeration reduces respiratory metabolism, inhibits pathogen incidence, and mitigates fruit decay, thereby delaying tissue senescence and extending storage life.



Key Milestone in 1851: James Harrison of Australia designs and builds the world's first refrigeration compressor and auxiliary equipment.

Fruits & Temperatures

- Temperature-sensitive fruits require proper storage temperatures and cooling regimes.
- Intermittent gradient cooling is recommended to minimize the risk of blackheart and flesh browning.



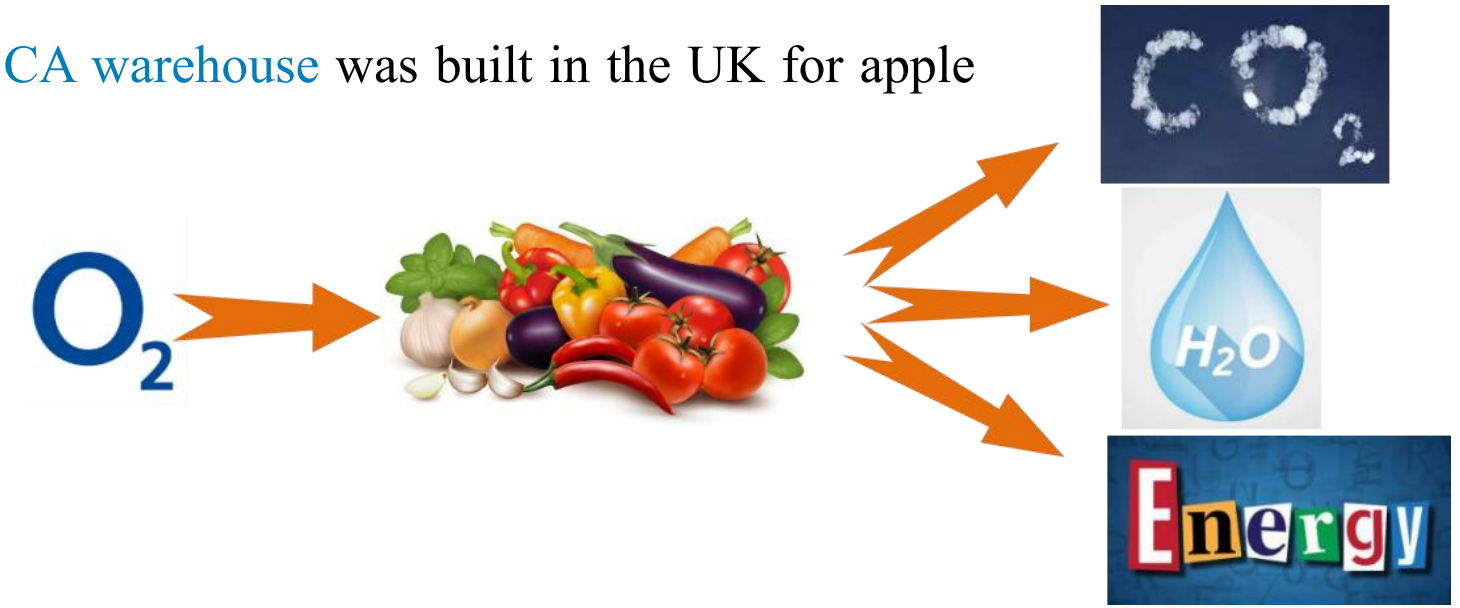
Six Major Iterative Temperature Stages

Three Revolutions in Modern Storage Technology

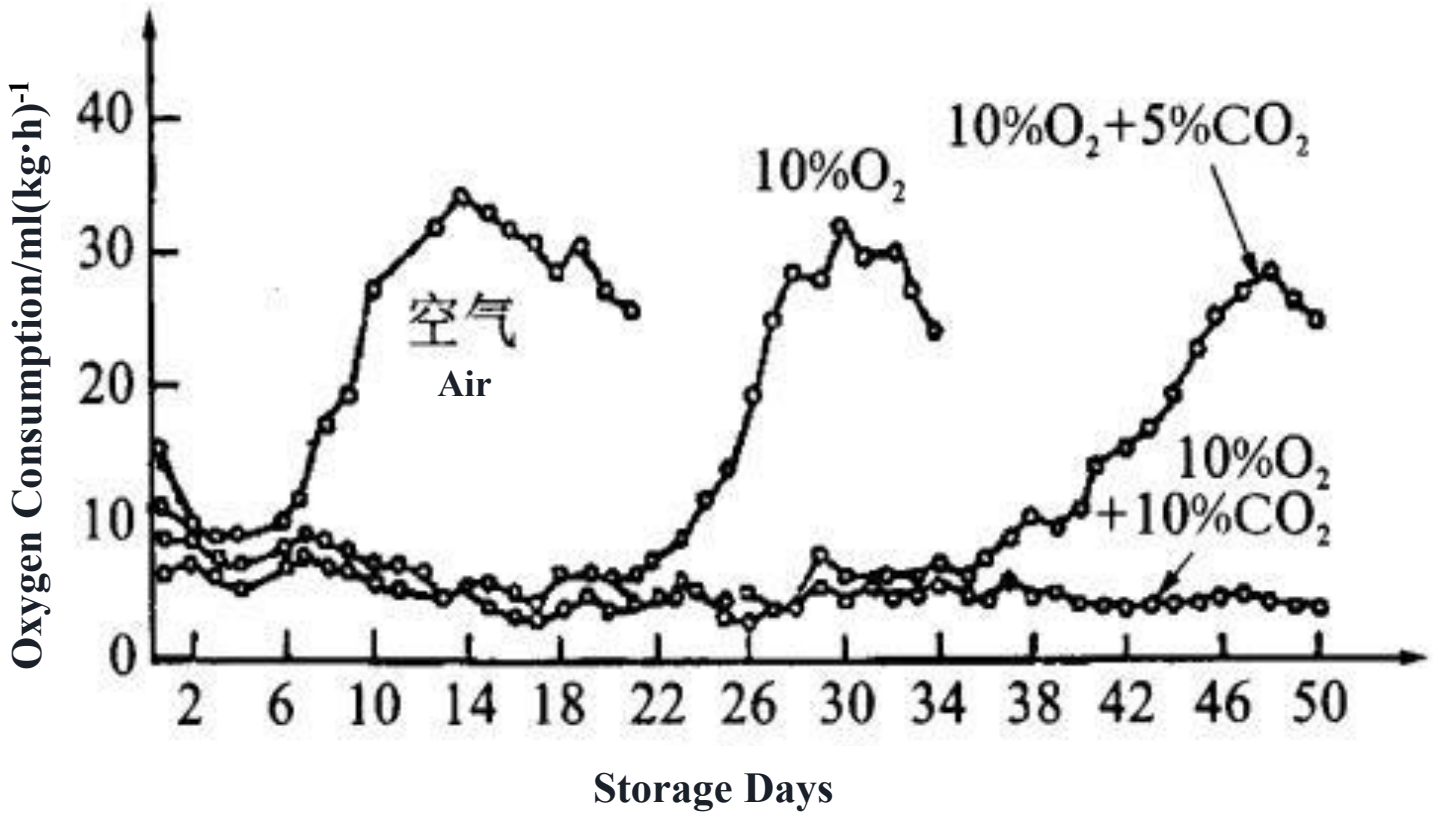
Controlled-atmosphere (CA) storage— The Second Preservation Revolution

Preservation Principle: Lowering O_2 and increasing CO_2 can reduce respiration intensity, delay the respiratory peak and inhibit ethylene production.

Key Milestone in 1928: the world's first CA warehouse was built in the UK for apple storage, with successful results.



Effects of O_2 and CO_2 concentrations on banana respiration



Three Revolutions in Modern Storage Technology

Hypobaric storage — The Second Preservation Revolution

Preservation Principle: Reduced pressure can create low-oxygen conditions, accelerate outward diffusion of ethylene from fruit tissues, so as to change the gas composition of the fruit storage environment and extend storage life.



Key Milestone —1975: First commercial hypobaric storage equipment appeared in the United States.

Examples



Apple storage life can be extended by 50% using hypobaric storage.



Bananas can be stored for about 120 days when pressure is reduced to 10.7-20.0 kPa.

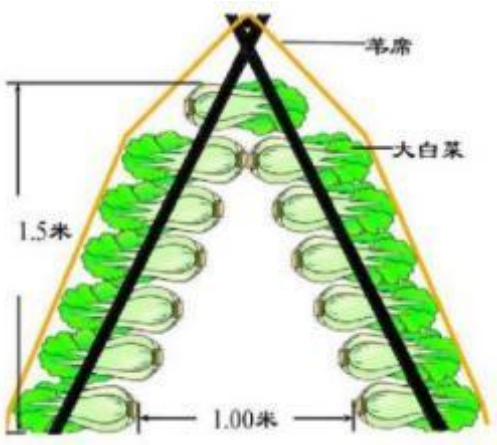
02

Smallholder-Friendly Technologies

-Simple Storage

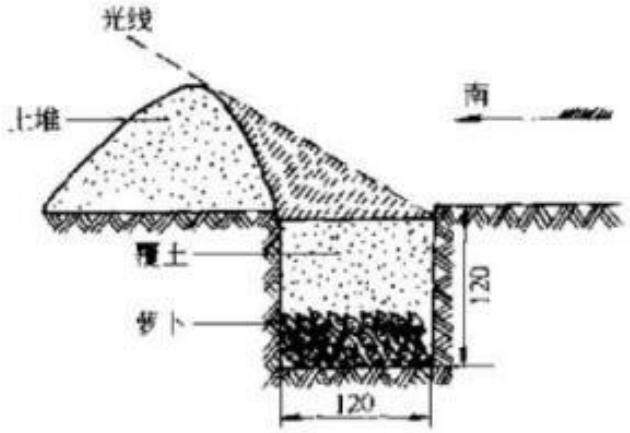
Simple Storage—Natural-Cooling Storage

Simple storage, also called natural-cooling storage, is a simple and traditional storage method.

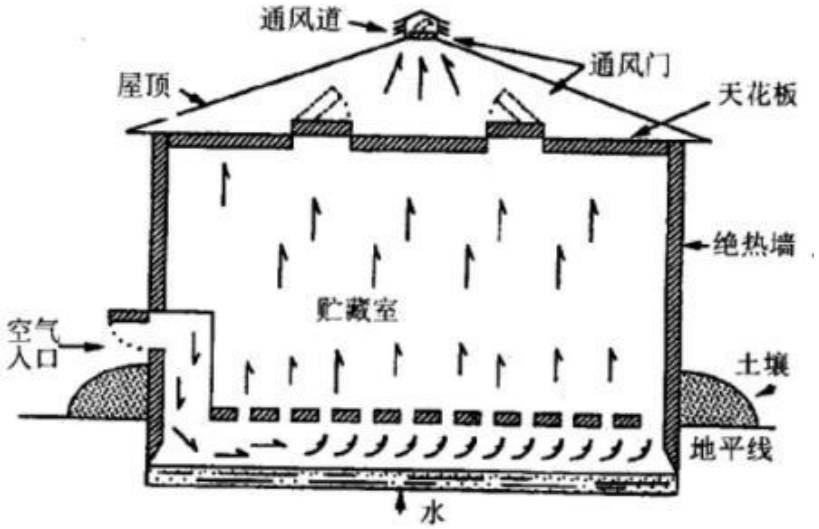


Pile storage (stack storage)

For Chinese Cabbage



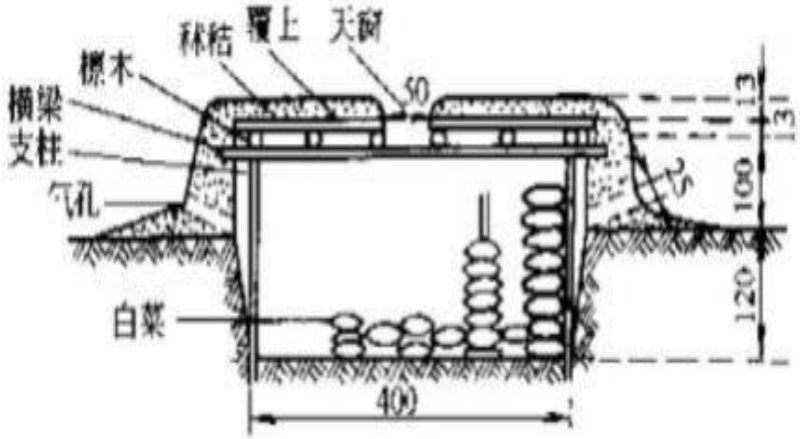
Trench storage
Radish burial storage



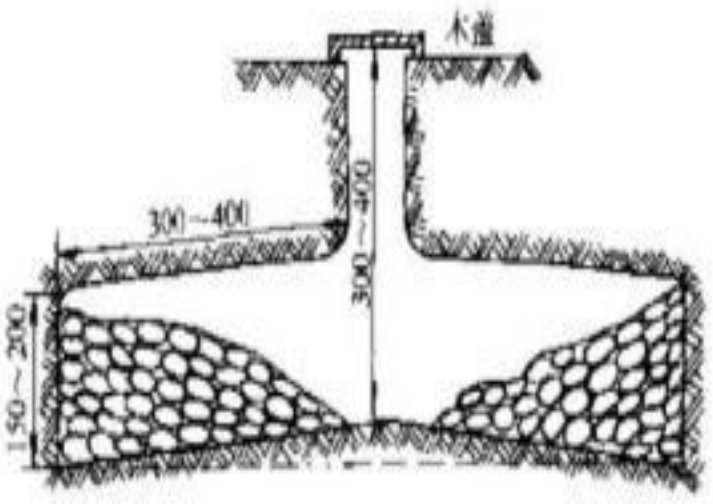
Ventilated storage

Simple Storage—Natural-Cooling Storage

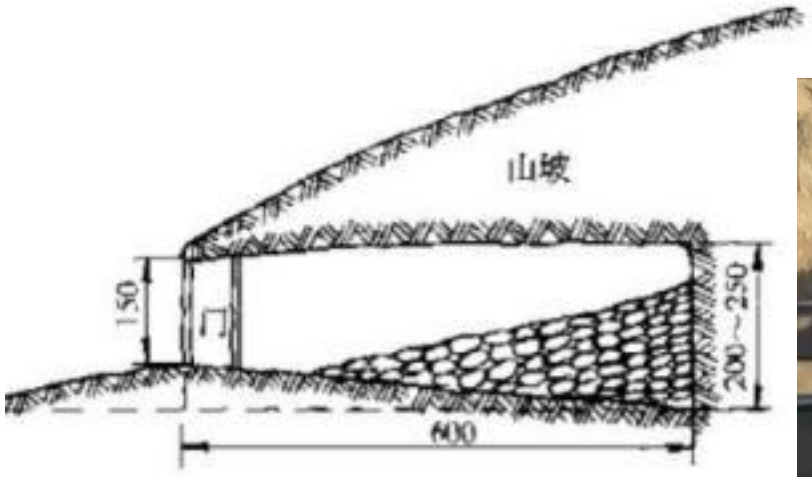
Cellar storage (Well, shed and cave cellars)



Shed cellar



Well cellar



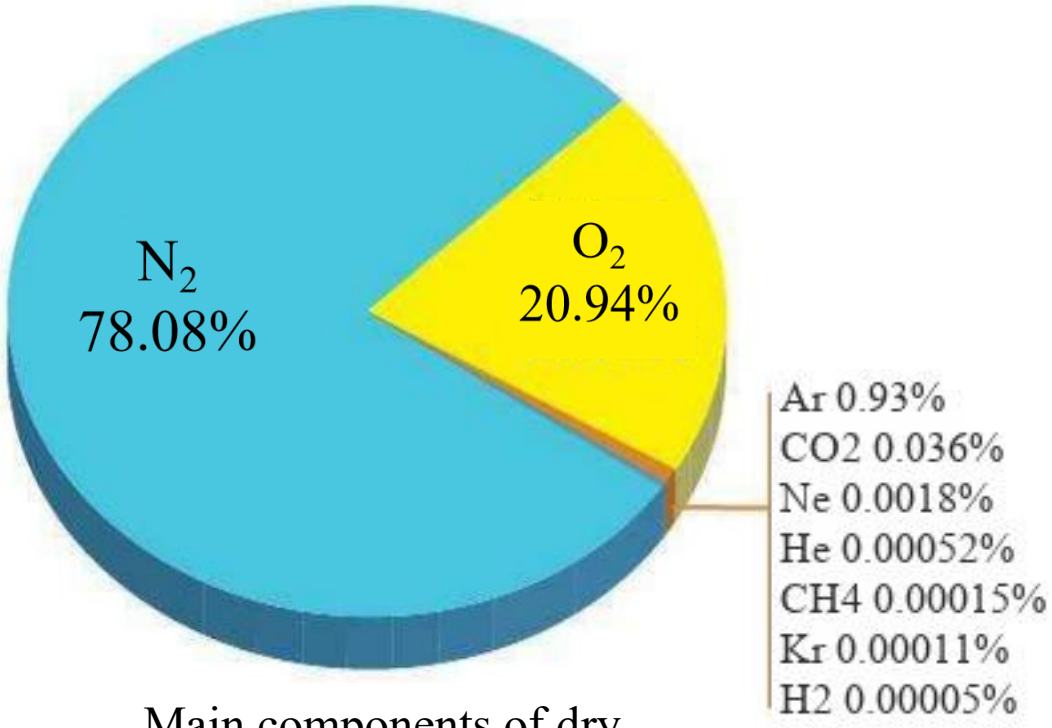
Cave cellar



03

Smallholder-Friendly Technologies

-Controlled Atmosphere Storage



Main components of dry clean air



How can the gas composition in the storage environment be adjusted?



Adjusting Storage-atmosphere Composition Methods

1. Natural Oxygen Reduction



Principle

Fruit respiration consumes O_2 and produces CO_2 in sealed environment.

Materials

Individual fruit packaging: 0.010–0.015 mm Polyethylene bags

Sealed plastic tents: 0.07–0.20 mm Polyethylene or non-toxic PVC film

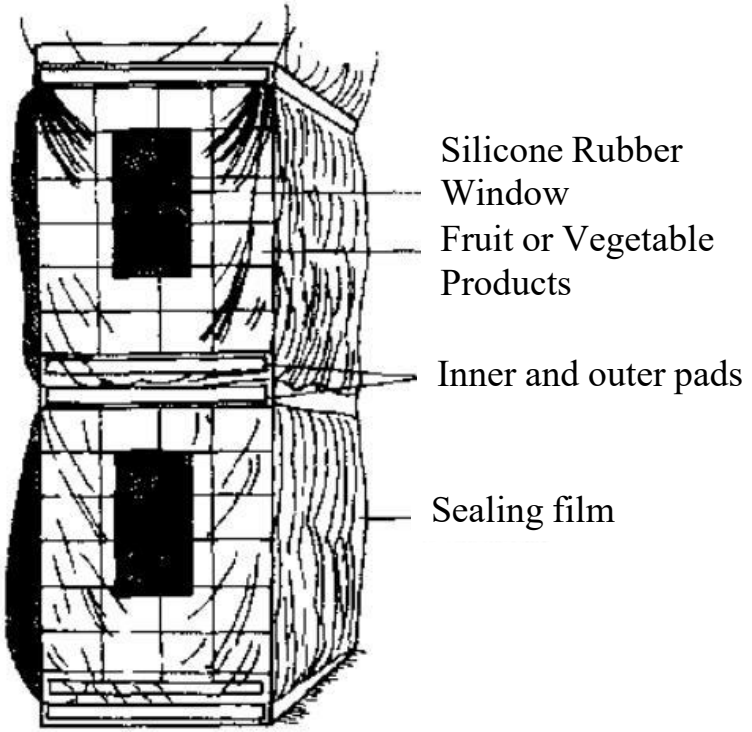


Pros & Cons

- ✓ Low storage cost and simple operation
- ➢ Long time required to reach target O_2/CO_2 levels.
- ➢ Gas composition difficult to maintain stably during operation.

Adjusting Storage-atmosphere Composition Methods

2. Silicone-window modified atmosphere



Principle

Silicone rubber window with high gas permeability and CO_2/O_2 selectivity is embedded in a plastic bag or tent, enabling automatic gas exchange driven by partial pressure difference between inside and outside.

Material

organosilicon polymer with high gas permeability (100-400 times higher than ordinary film) and high CO_2/O_2 permeability ratio

Pros & Cons

- ✓ Automatic regulation and low operating cost.
- ➢ Precise design required and not universal– window area and thickness must be accurately matched to product respiration rate, package size, and storage condition.

Adjusting Storage-atmosphere Composition Methods

3. Combined oxygen reduction



Principle

A gas generator is used in the early storage stage to rapidly establish the required atmosphere in the CA warehouse, then switched to natural oxygen reduction (fruit respiration) for ongoing operation and management..

Materials

Gas generator (produces N_2 or low-O_2 gas by combustion or membrane separation); CA warehouse with standard sealing and gas-tight construction.

Pros & Cons

- ✓ Fast atmosphere establishment at startup.
- ✓ Saves daily operating costs after switching to natural reduction..
- ➢ Requires both gas generation equipment and a well-sealed storage facility.
- ➢ careful transition management

04

Practical Application Cases

Four Key Factors in Storage and Preservation Control

Factor	Contribution	Major Effects	Control Technologies
Temperature	60%–70%	Respiration, chilling injury, freezing injury	Pre-cooling and low-temperature storage and transportation facilities
Humidity	10%–15%	Transpiration, wilting	Humidification, preservation packaging
Gas Composition	10%–15%	Respiration, gas injury	Controlled-atmosphere facilities, MAP
Decay Control	10%–15%	Mold growth, decay	Anti-mold preservatives

The technical system primarily relies on low-temperature pre-cooling, storage and transportation facilities and equipment, supplemented by controlled-atmosphere technologies, preservation packaging, and antimicrobial preservatives.

Pre-cooling



Mandatory ventilation pre-cooling



Differential pressure pre-cooling



Vacuum cooling



Add ice for pre-cooling



Immersion water pre-cooling



Spray-type water pre-cooling

Preservation Packaging Materials

Moisture Permeability and Anti-fogging Properties: Prevent moisture loss from stored products while avoiding condensation inside the package.



Gas Permeability: Prevent gas injury and enable passive modified-atmosphere packaging (MAP).

- For CO_2-sensitive fruits as apples and pears, packaging with high CO_2 permeability can be used.
- For climacteric fruits and vegetables, passive MAP can be used.



Antimicrobial Properties: Incorporating antifungal additives such as nanosilver, titanium dioxide, and hydroxyapatite helps inhibit decay and deterioration of fruits and vegetables.

Ethylene Adsorption: Incorporating active nanomaterials can inhibit and adsorb ethylene, thereby delaying postharvest ripening and softening of fruits and vegetables.

Storage and Preservation-Fruits



Climacteric Fruits (e.g., apples, pears, kiwifruits, and bananas): Harvest and place them in storage before the respiratory climacteric peak, cool promptly after harvest, and use controlled-atmosphere storage where appropriate.



Ethylene-sensitive Fruits (e.g., kiwifruits, bananas, and European pears): Remove ethylene promptly from the storage and transportation environment and avoid storing them together with ethylene-producing products.

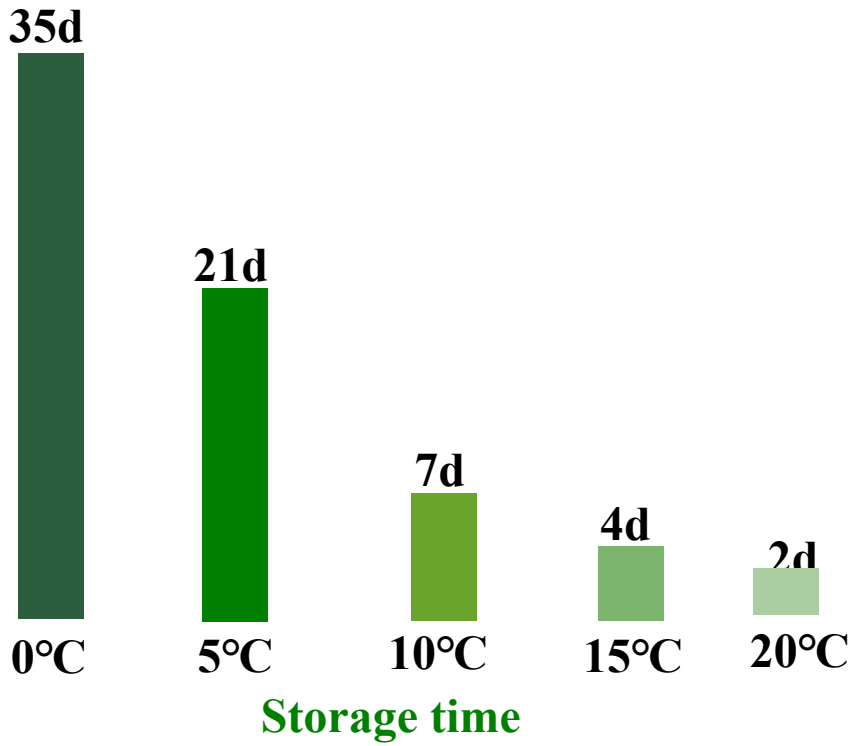


CO_2-sensitive Fruits (e.g., Ya pears, Golden pears, Fuji apples, and winter jujubes): Use packaging with high CO_2 permeability and ensure adequate ventilation and air exchange in the storage facility.

Storage and Preservation-Vegetables-Broccoli

Temperature Control

Broccoli showed the best storage performance at 0°C, with a storage life of up to 35 days. In contrast, it could be stored for only 2 days at 20°C.

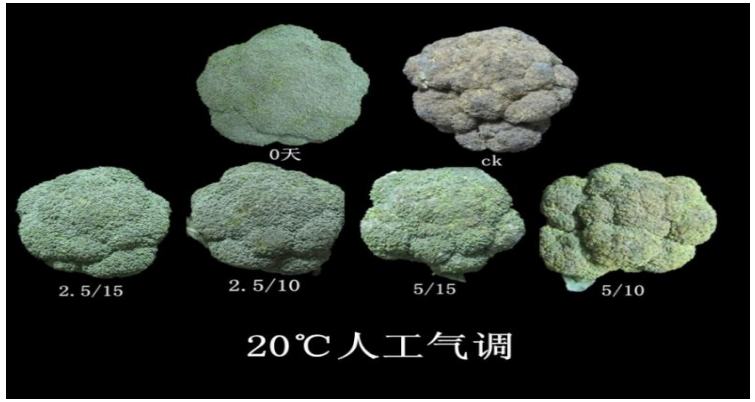


Controlled-Atmosphere Preservation

An O_2/CO_2 atmosphere of 2.5%/15% was most effective in delaying yellowing and senescence of broccoli heads.



0°C Controlled-Atmosphere Preservation

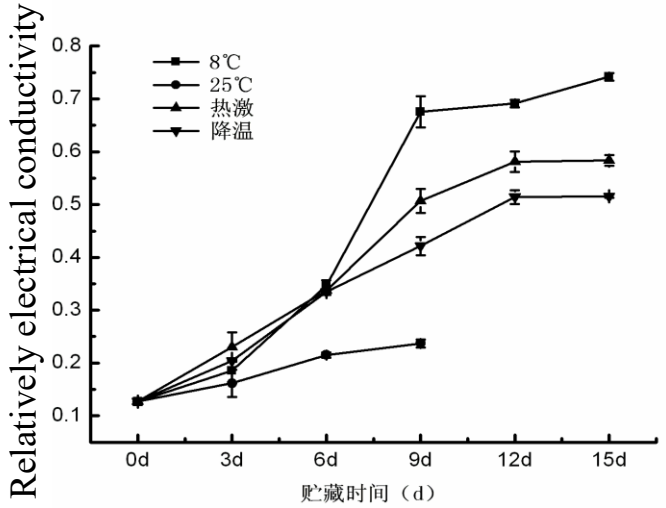


20°C Artificially Controlled-Atmosphere Preservation

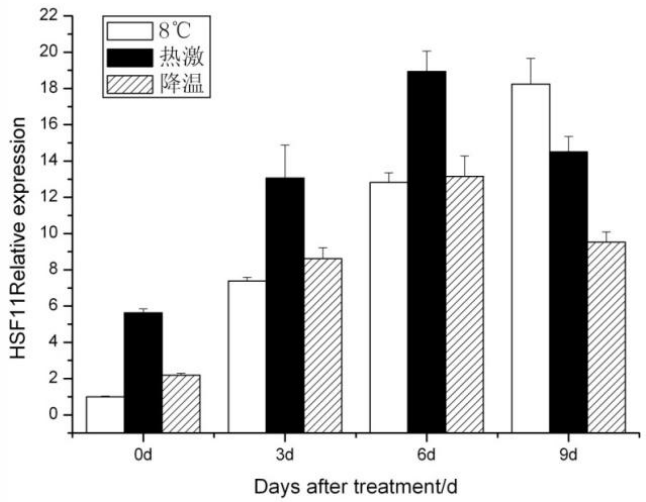
Storage and Preservation-Vegetables-Cucumber

Heat-Shock Treatment for Chilling Injury Control

Heat-shock treatment can inhibit the increase in electrical conductivity of cucumbers and alleviate chilling injury in cucumber fruits.

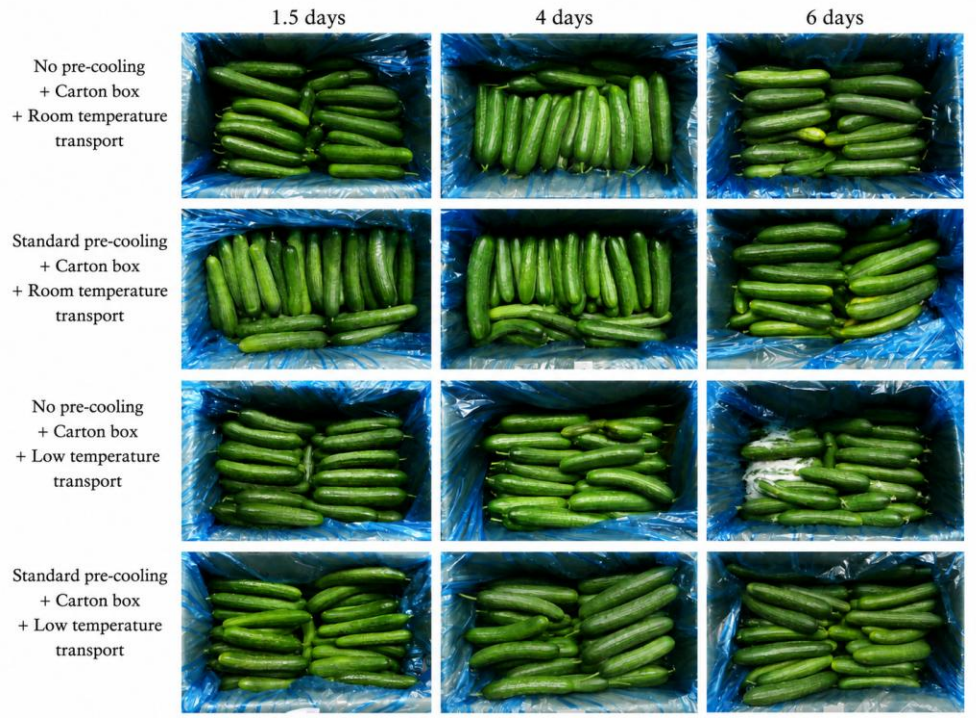


Storage Duration (Days)



Preservation Packaging Technology

Microperforated preservation films and POF heat-shrink films can delay ripening and senescence of cucumbers and increase marketable yield.



In conclusion:

The core of fruit and vegetable postharvest storage and preservation technology lies in **five key elements: temperature control, humidity control, atmospheric composition control, ethylene management, and disease prevention**.

Through **pre-cooling, controlled-atmosphere storage, humidity regulation, ethylene inhibition, antimicrobial packaging materials, and continuous monitoring**, the shelf life of produce can be significantly extended, losses reduced, and commercial value enhanced.

WFP World Food Programme

2 ZERO HUNGER

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