Fruit and Vegetable Drying Technologies and Equipment





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Sharing for Learning

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01

Overview of Fruit and Vegetable Drying

Background— Why Drying 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)

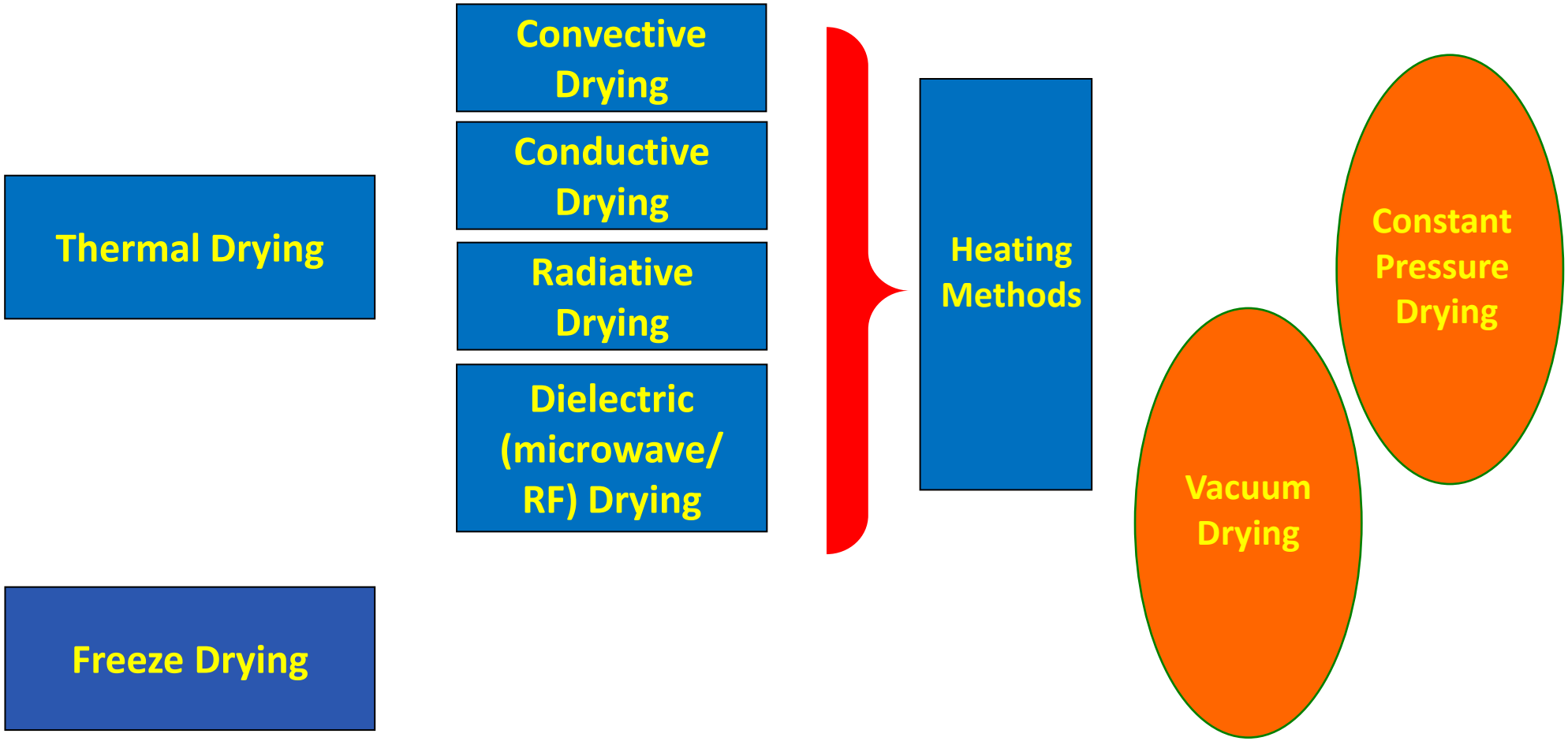
Dry product preservation principle: Through appropriate processing methods, the moisture content of fruits and vegetables can be reduced to a level at which microorganisms are unable to grow, allowing the products to remain in a low-moisture state suitable for long-term storage.



Drying Technology Delivers:

- Inhibits microbial growth and extends shelf life.
- Creates new product forms.
- Achieves desired color, flavor, texture, and physical forms.
- Improves transportation efficiency by reducing volume and weight.

Classification of drying technologies



Classification of drying technologies



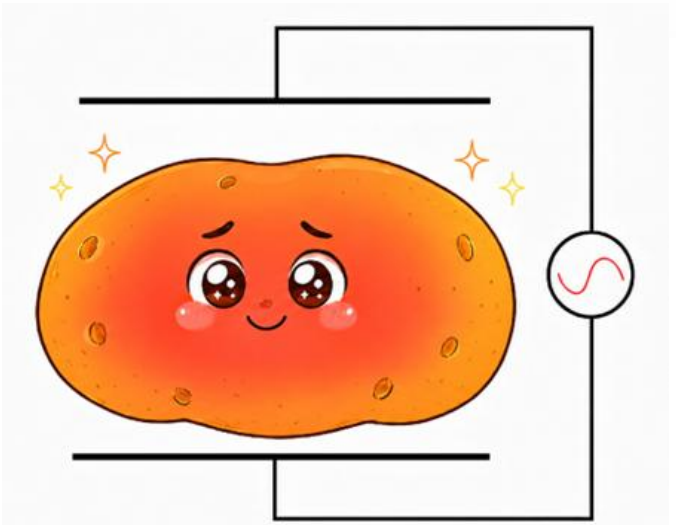
Convective Drying



Radiative Drying



Conductive Drying

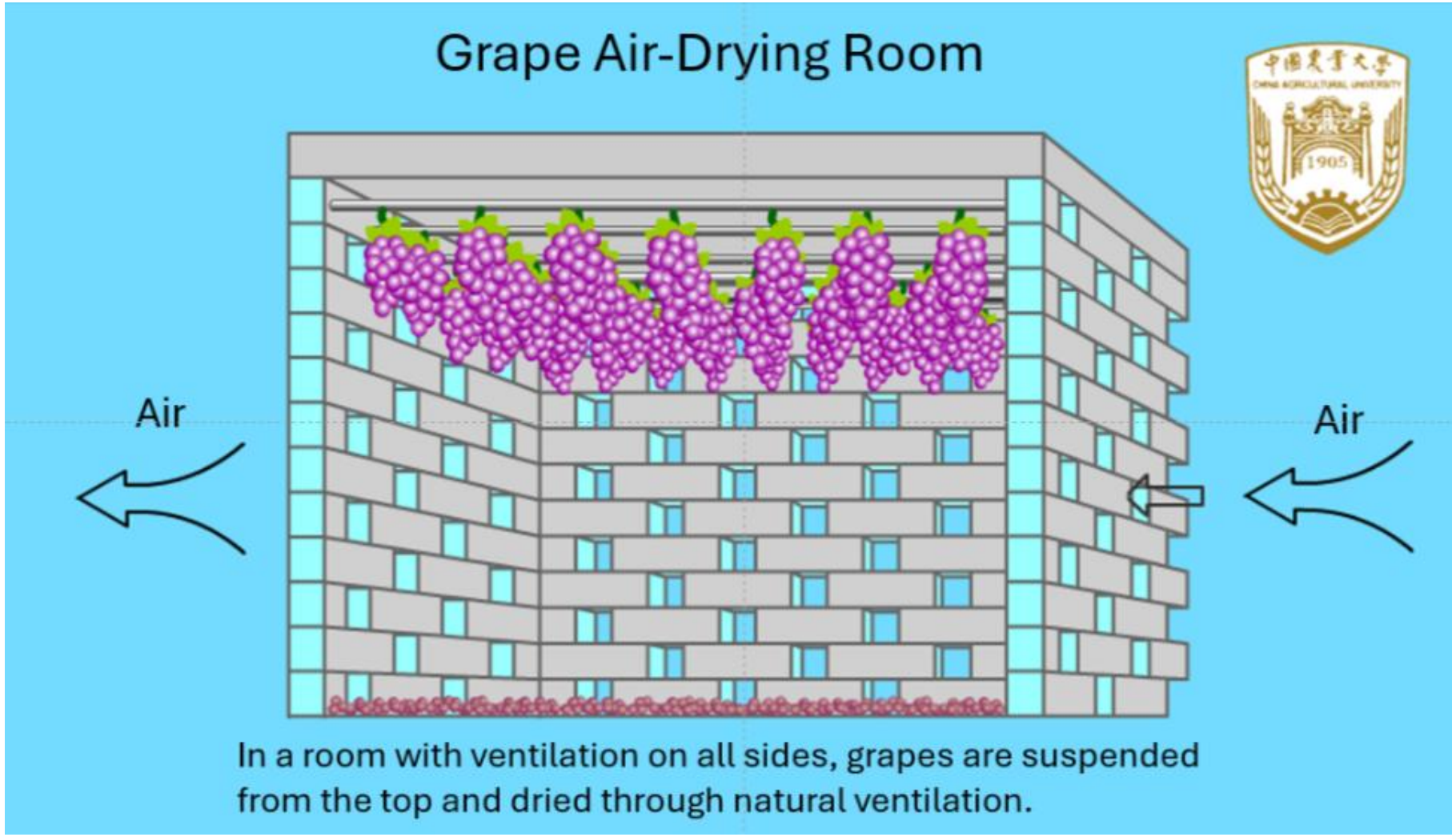


Dielectric Drying

02

Smallholder-Friendly Drying Technologies and Equipment

Convective drying



Cabin Dryer

Equipment types

Small → oven; Large → drying room (batch operation)

Material placement

Trays or suspended on brackets

Airflow

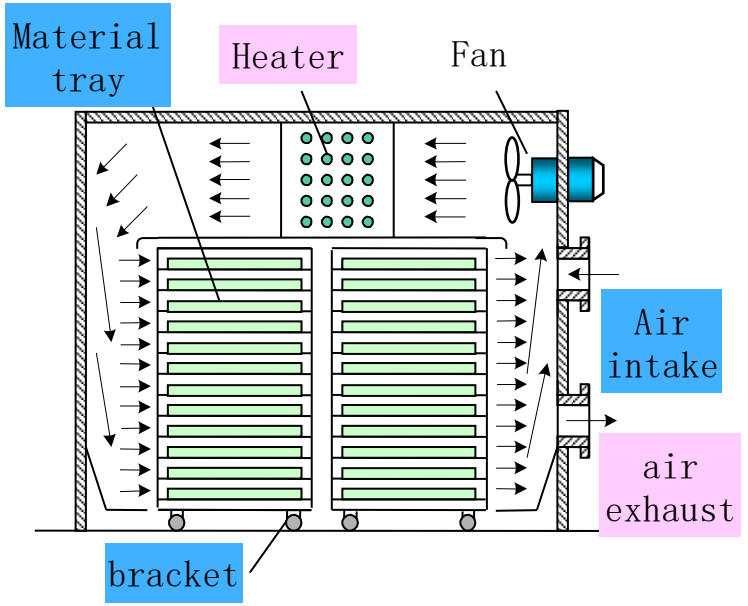
Heated air flows parallel to material surface

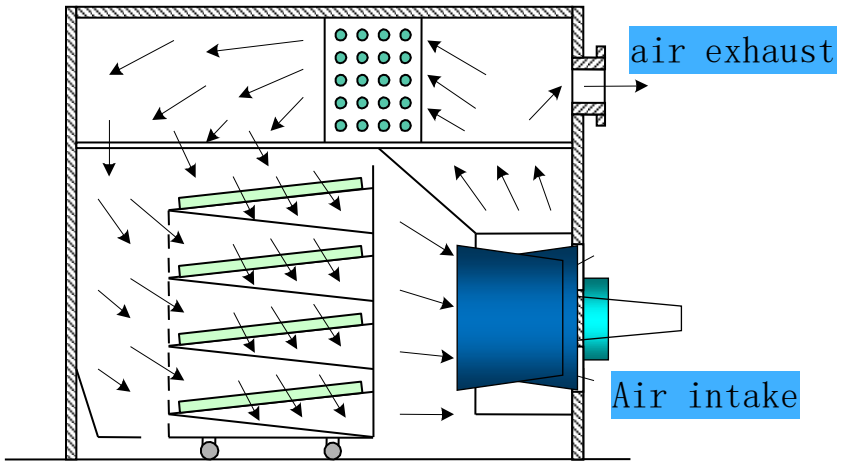
Air circulation

Partial exhaust discharged; partial recycled and mixed with fresh air

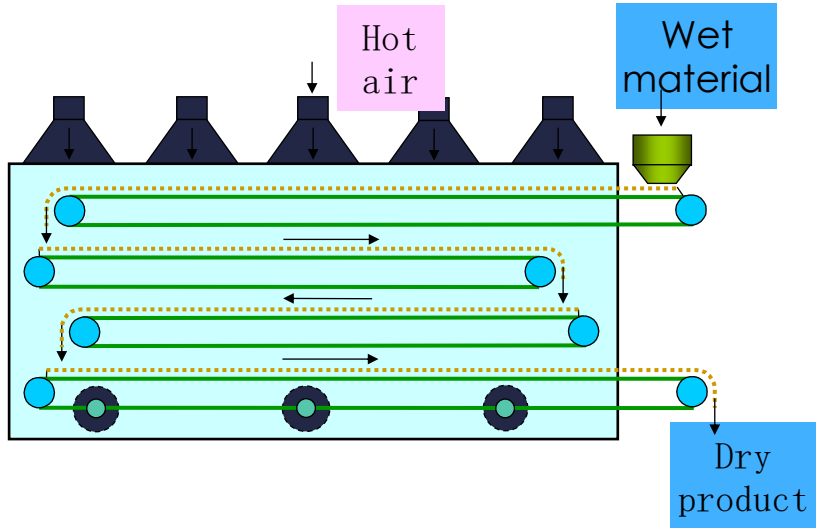
Pros & Cons

- ✓ Strong adaptability to materials and different scales.
- ➢ Low thermal efficiency and uneven product quality.





Conveyor-belt Dryer



Equipment types

Belt passes through a channel of one or several heating units

Material placement

Evenly distributed onto conveyor belt

Airflow

Hot air passes top-to-bottom or bottom-to-top through material layer — ensuring uniform drying

Operation

Different drying sections can be operated with independent process parameters.



Pros & Cons

- ✓ Continuous operation and uniform drying
- ➢ Not suitable for sticky or highly hygroscopic materials

Rotary Dryer

Principle: Rotation lifts material with boards → material is sprinkled through air stream → enhances gas-solid heat and mass transfer

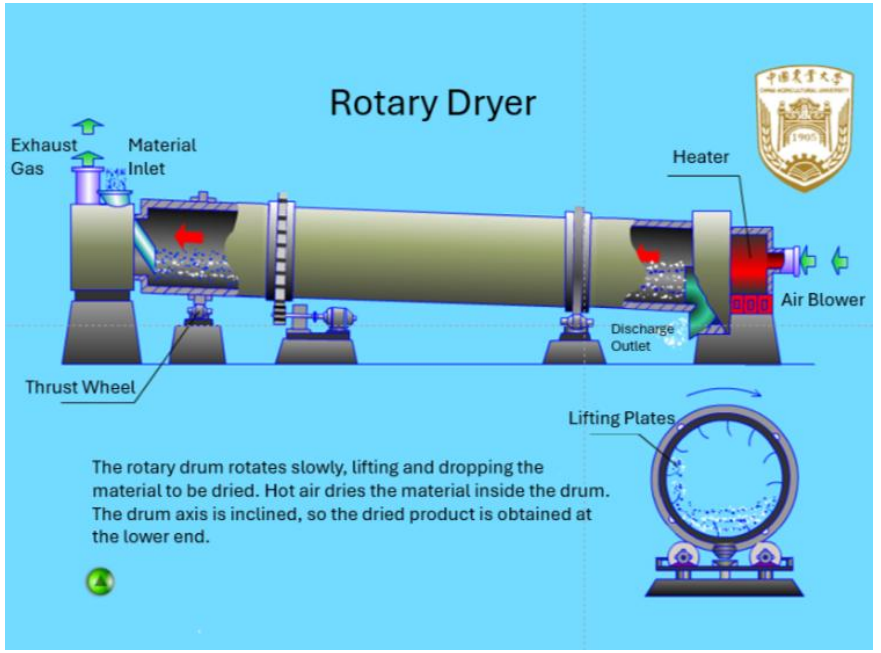
Main body: Cylinder equipped with axial lifting boards

Structure: Slightly tilted; rotating by gear drive

Material flow: From higher end to the lower end

Airflow

Hot air from either end; countercurrent or downstream gas-solid contact



Pros & Cons

- ✓ High capacity, versatile, flexible airflow
- ➢ Dust generation, not for sticky/heat-sensitive materials

Conductive drying

Drum Dryer

Structure

Hollow rotating drum; internally heated by steam or thermal oil

Material feeding

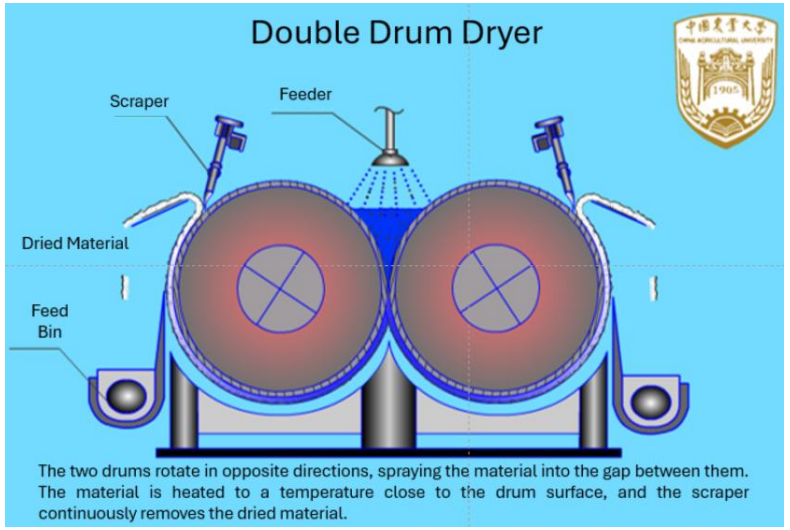
Auxiliary roller (high-viscosity) / Dip feed (low-viscosity) / Spray feed (heat-sensitive)

Operation

Material spread as thin film (0.15–1.5 mm) on drum surface → dried within 5–30 s → scraped off by blade

Pros & Cons

- ✓ High thermal efficiency; short drying time
- ➢ Small heat transfer area; limited throughput; dust generation





Radiative drying

Infrared Dryer

Principle

Infrared radiation absorbed by material → molecular vibration → heat generation

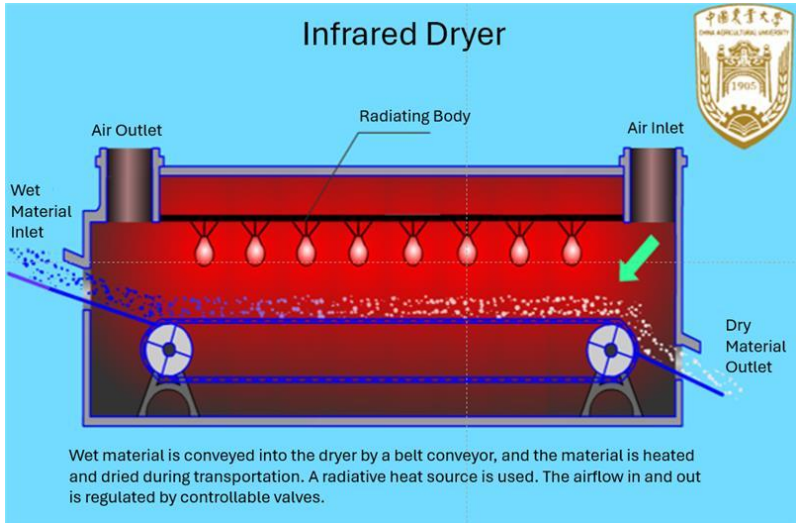
Wavelength

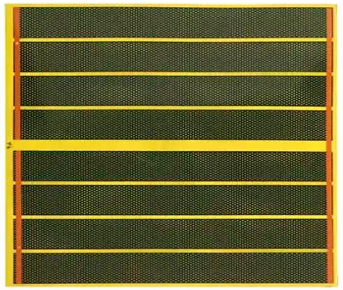
Near-infrared (NIR): 0.75–2.0 μm — strong penetration, suitable for thick-layer materials

Mid-infrared (MIR): 2.0–4.0 μm — main absorption peak region of water molecules

Pros & Cons

- ✓ Fast drying; high thermal efficiency; good quality; compact design
- ➢ Limited penetration (surface only); wavelength must match material; higher electric cost





Graphene infrared heating plate



Carbon fiber infrared heating plate

Solar Drying Shed



Principle

Greenhouse effect — transparent cover traps solar radiation, raises internal temperature, accelerates moisture evaporation.

Material placement

Internal perforated racks or shelves for uniform exposure to heat and airflow



Ventilation

Inlet and outlet openings allow natural convection

Removes humid air to prevent mold growth

Pros & Cons

- ✓ Low operating cost (free solar energy)
- ✓ Cleaner than open-air sun drying
- ➢ Weather-dependent — ineffective at night or on cloudy/rainy days
- ➢ Slow drying rate; limited capacity.

Cabinet Solar Dryer







Working Principle

Solar photovoltaic (PV) panels generate electricity to power fans and heating elements, accelerating the drying process;

Multi-layer tray design with hot air circulating through the material layers for uniform drying.

Key Advantages

- Fully enclosed structure – dust-proof and insect-proof, ensuring hygiene;
- Suitable for mango, banana, tomato, chili, herbs, and various other materials;
- Low operating cost and easy maintenance.

Vacuum freeze drying

Principle

Material frozen → ice crystals sublime directly under vacuum (solid → vapor), bypassing liquid phase

Three Stages

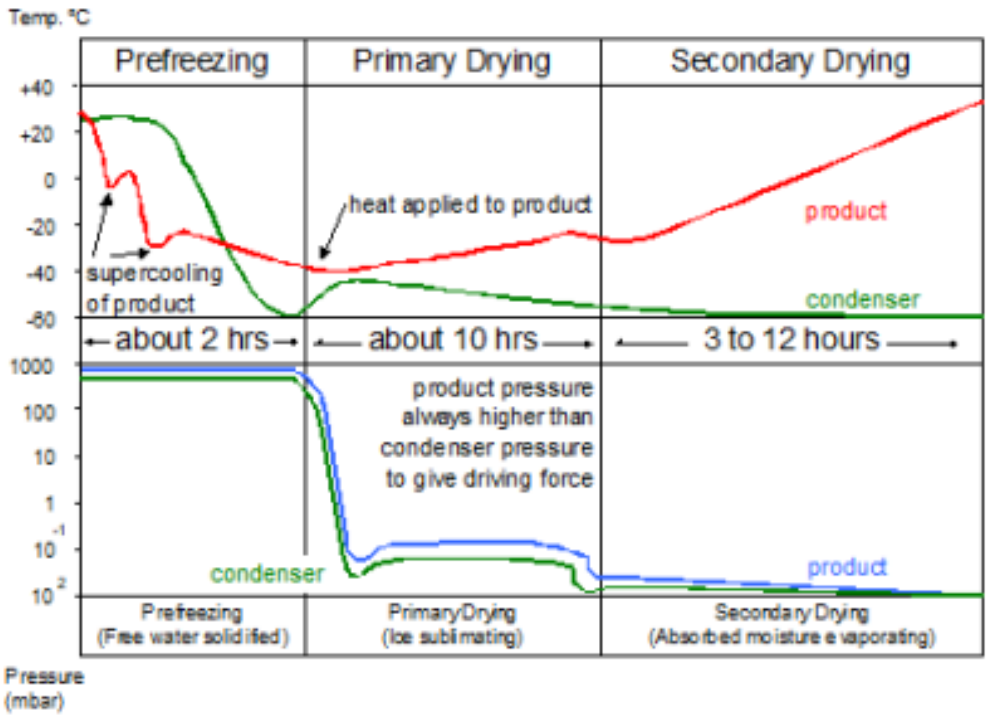
Pre-freezing (–30 °C to –50 °C): Forms ice crystals; fixes material structure

Primary drying (sublimation) (0.1–0.6 mbar, –10 °C to 0 °C): Removes 90%–95% of total water

Secondary drying (desorption) (20–40 °C): Removes bound water; final moisture < 1%

Pros & Cons

- ✓ Superior quality (retains color, flavor, aroma, shape); excellent rehydration; ideal for heat-sensitive materials
- ➢ Very high energy consumption; extremely long drying time; high capital cost; batch operation

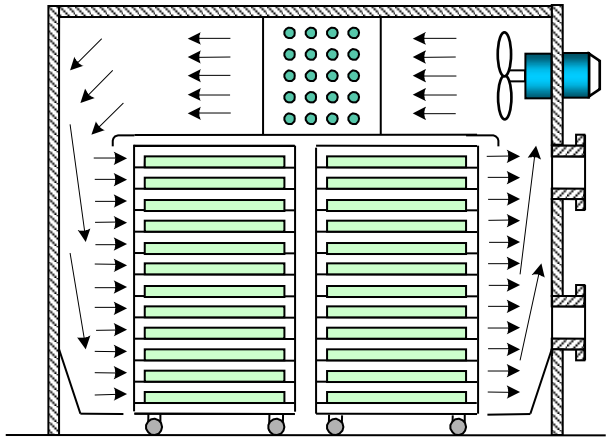






Practical Application Cases

Drying room is the most commonly used drying method in drying of fruits and vegetables due to the strong adaptability, it can handle multiple materials simultaneously. However, the low thermal efficiency is a big challenge.

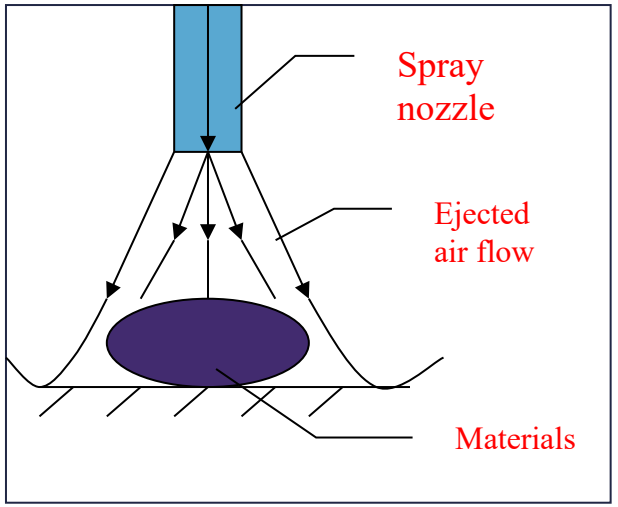


adjusting

- hot air velocity → Hot air impingement drying
- pressure → Pulsed vacuum drying
- heating source → Multi-heat source heat-pump drying
- intelligent control → Intelligent hot air drying

Air impingement Technology

Air impingement technology is a technique that involves spraying pressurized heated air through a specific-shaped nozzle to directly impact the surface of materials and remove moisture.



Technical characteristics and advantages：

- High air velocity, short airflow path, and high convective heat transfer coefficient (typically 5 times or even more than 10 times that of hot air drying)
- Short drying time (50% to 70% of that required for hot air drying) and low energy consumption (20%-30% lower than that of hot air drying).







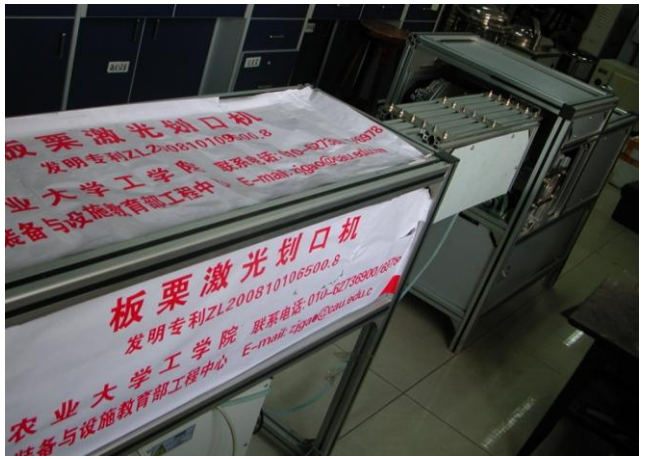




Application case: Peeling of fruits, vegetables, and dried nuts, as well as nut shell bursting













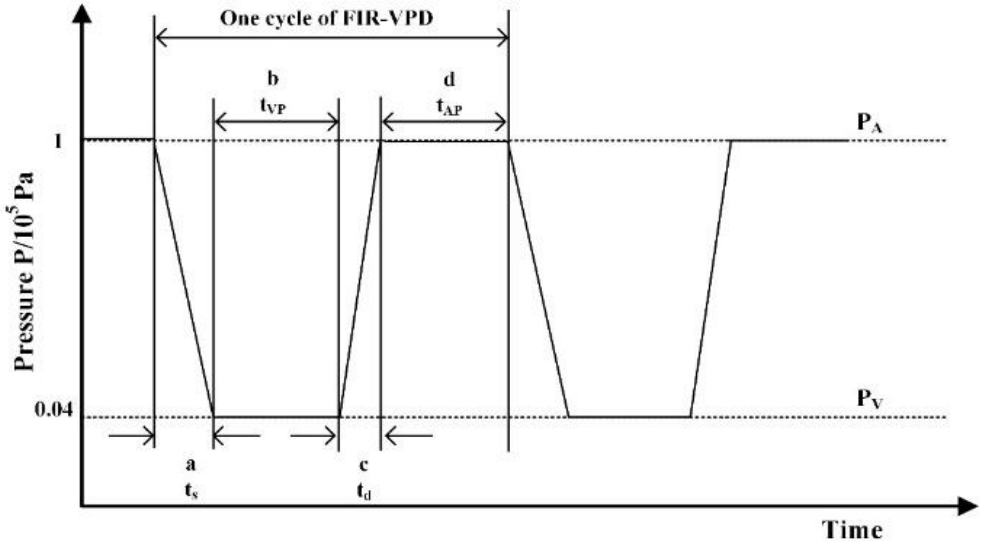
Pulsed Vacuum Drying Technology

Challenge: During conventional vacuum drying, the water vapor partial pressure inside and outside the material tends to remain in equilibrium for an extended period, resulting in relatively low drying efficiency.

Principle: Pulsed pressure cycling breaks the equilibrium and mechanically alters the material's microstructure to facilitate moisture diffusion, while the vacuum-generated low-oxygen atmosphere chemically suppresses enzymatic browning.

Characteristics:

1. Significantly increases drying rate;
2. The drying energy consumption is reduced by more than 25% compared to vacuum drying;
3. The product color and heat sensitive nutrients are well preserved.



The pressure in the drying chamber shows periodic pulsed fluctuation

Application case: Pulsed vacuum drying of high-sugar fruits with waxy surfaces

Challenge: Low drying rates are commonly observed in fruits such as mango and banana (due to their high sugar content) and in apricot and goji berry (due to the waxy layer covering their surfaces).

The main characteristics by pulsed vacuum drying:

Short drying time: approximately ¼ of that by hot air drying.

Superior product quality:

- Polysaccharide content: **2.5×** higher than that by hot air drying (the same temperature for goji-berry);
- Excellent color retention;
- Porous surface microstructure and high rehydration capacity.







Heat-pump Drying Technology

Principle: Based on the reverse Carnot cycle, where the refrigerant absorbs heat from the exhaust air or environment and releases it at the condenser to heat the drying medium

Main body: Heat pump unit + drying unit + control unit

Pros & Cons:

- ✓ High energy efficiency(1 kWh electricity produces 3–4 kWh of heat), significant energy savings, operating cost approximately 1/3–1/4 of electric heating
- ➢ Higher initial investment, performance degradation at low ambient temperatures, long drying cycles



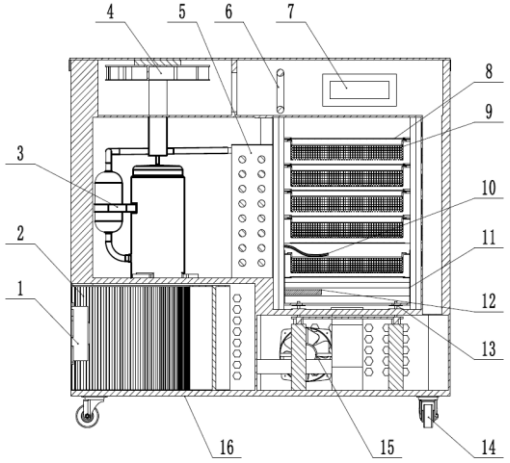
Application case: Infrared-Assisted Energy-Efficient Heat-Pump Drying of vegetables

Challenges: slow early-stage heating, low late-stage efficiency, poor energy efficiency, and unstable product quality of single heat-pump drying

Core Technology: Air-source heat pump + carbon-fiber far-infrared heaters / electric heating tubes (auxiliary) for multi-heat-source coupled supply

Operation: Rapid heating (multi heat source in first stage) → energy-efficient dehumidification (using heat-pump in middle stage) → enhanced moisture migration (infrared assisted in late stage).

Applications: Thin-layer drying of sheet-like, strip-like, and granular materials with diameters below 15 mm.



1. Exhaust Fan 2.Heat Exchanger 1 3. Compressor 4. Fan 5.Heat Exchanger 2 6. Electric Heater 7. Touchscreen 8. IR Panel 9. Tray 10. Temperature Sensor 11. Rack 12.Temp./RH Sensor 13. Weighing Support 14. Caster 15. Cooling Fan 16. Drying Chamber



Honeysuckle



Daylily



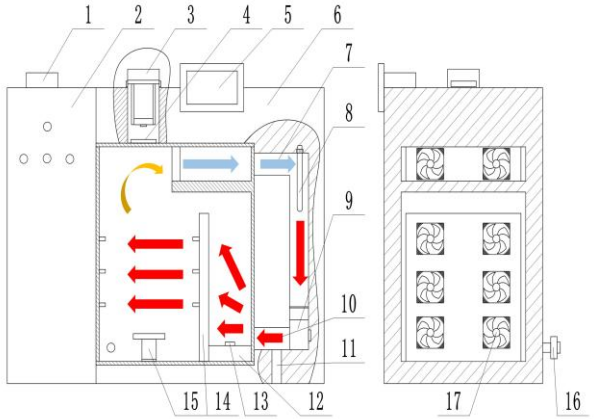
Prune



Yellow Mushroom



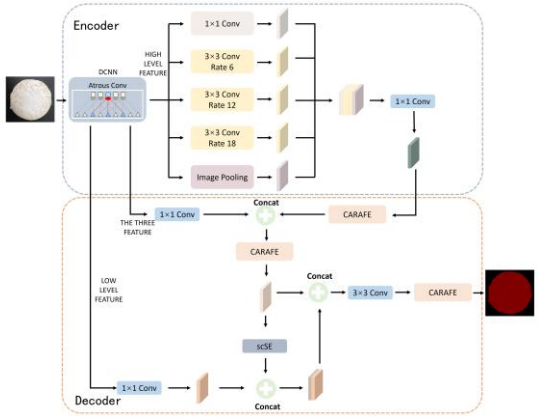
Intelligent Hot air drying with temperature and humidity process control

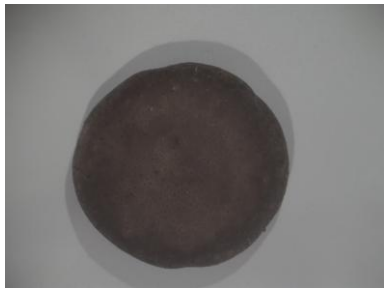




1. Computing and information processing unit 2. Distribution box 3. Computer Vision Component 4. Light source 5. Industrial control panel 6. Drying chamber shell 7. Heating pipe 8. Heating pipe 9. Centrifugal fan 10. Return pipe 11. Air inlet pipe 12. Water tank 13. Humidifier 14. Fan support 15. Load cell 16. Exhaust fan 17. Spoiler fan

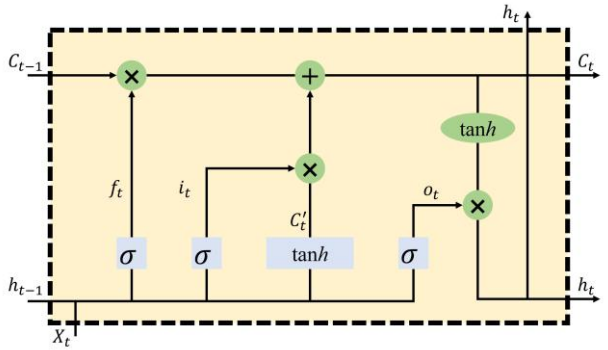
- DeepLabV3+ Semantic segmentation algorithm





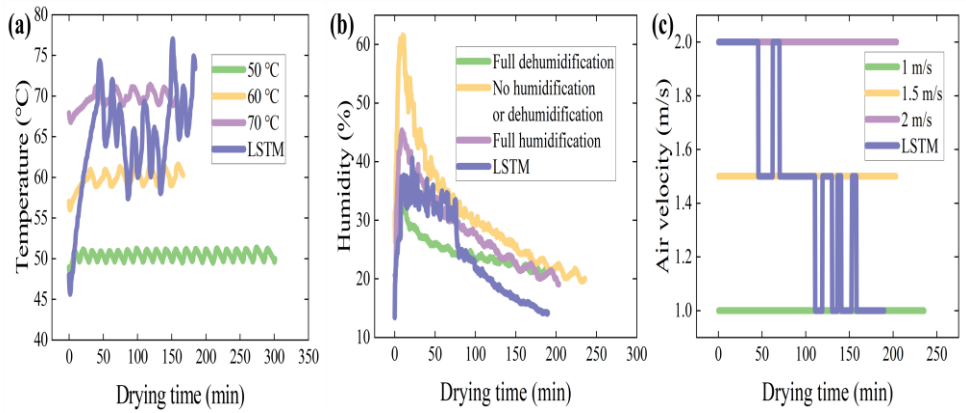
Appearance quality

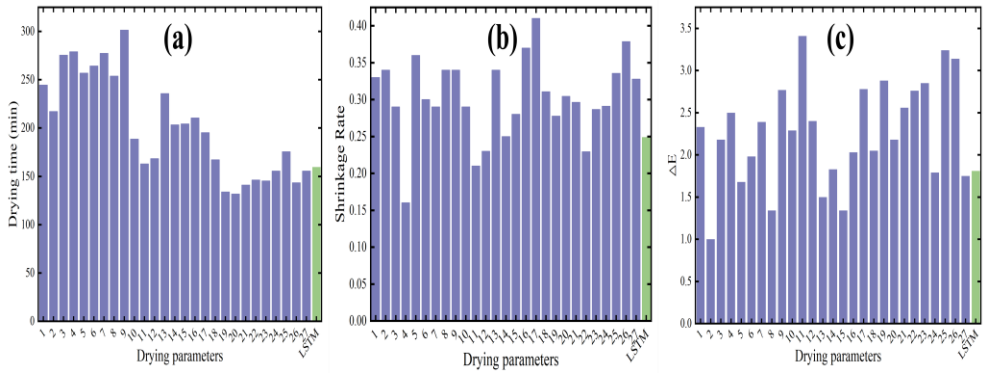
- Long Short-Term Memory networks

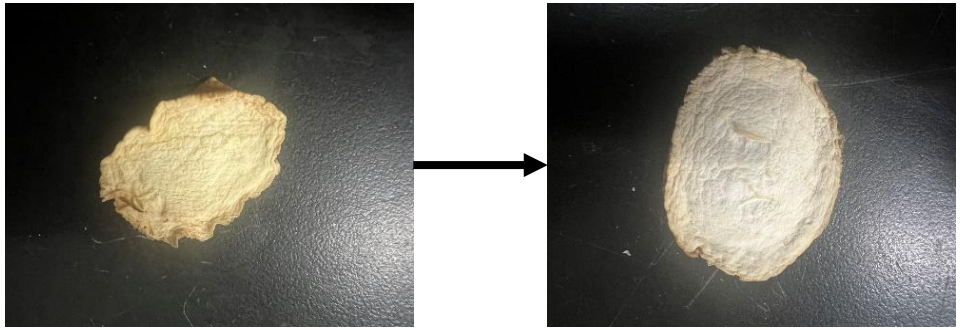


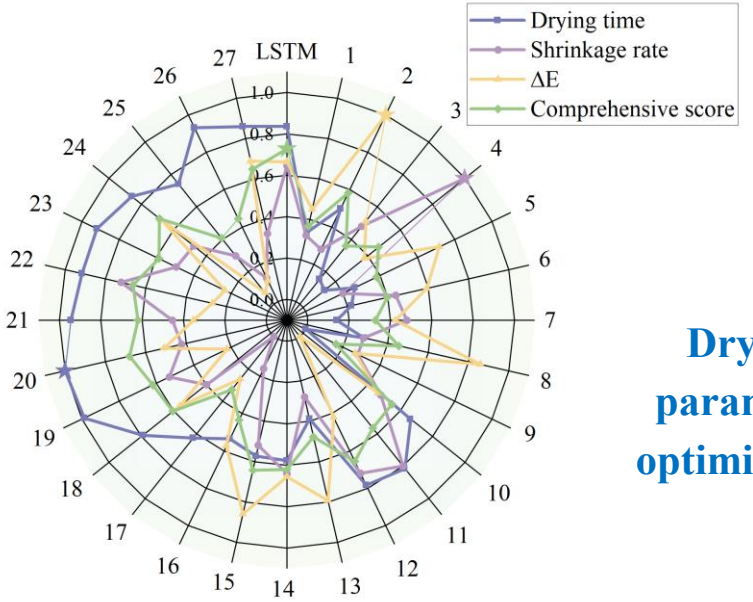
Parameter control

Application case: Intelligent Hot air drying of Pleurotus Eryngii









Drying parameter optimization

In conclusion:

The core of fruit and vegetable drying lies in efficient moisture removal to inhibit microbial activity and biochemical reactions, while preserving product quality (color, flavor, shape, and nutrients) and ensuring economical production.

Techniques such as hot air impingement drying, pulsed vacuum drying, heat pump drying, infrared-assisted drying, and intelligent control extend product shelf life, reduce losses, and enhance value through diverse product forms and superior quality.

WFP World Food Programme

2 ZERO HUNGER

WFP-China SSC Knowledge Sharing Platform

Thank You

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