



Post-Harvest Technology and Processing of Carrot (*Daucus carota* L.)

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Carrot (*Daucus carota* L.) is a nutrient-rich root vegetable, globally cultivated and consumed. Its high water content and soft periderm make it susceptible to physiological and microbial spoilage. This review integrates recent advances in harvesting, handling, storage, packaging, and processing methods that enhance post-harvest quality, extend shelf life, and add market value. Highlighted strategies include hydrocooling, chlorine-ozonation combined with *Lactobacillus plantarum*, temperature-controlled curing, and innovative drying methods. A thorough examination of packaging innovations (e.g., edible coatings, modified atmospheres), sensor-based sorting, and automation is also included. Emerging tools such as thermal imaging and machine vision assist in reducing losses. The article underscores the importance of regional adaptation, especially in resource-limited settings, with practical options like moist sand storage. Recommendations focus on integrating cost-effective technologies, optimizing nutritional retention, and aligning interventions with local production systems.

Introduction

Carrot (*Daucus carota* L.) ranks among the most produced root vegetables, with global output exceeding 40 million tonnes annually. Its nutritional profile—rich in carotenoids, phenolics, vitamins, and fiber—makes it a health-promoting food. Yet due to its high respiration rate and moisture content, carrots are vulnerable to dehydration, microbial decay, physical injury, and physiological disorders post-harvest. This article reviews advances in post-harvest technology and processing aimed at curbing losses, preserving quality, and enabling value-addition.

Harvest & Handling Techniques

Harvest Timing and Gentle Removal

Harvesting at physiological maturity (usually 90–110 days) during cool hours significantly reduces field heat and damage risk. Gentle manual or mechanized pulling with proper topping (~2–3 cm of foliage) helps minimize moisture loss and reduces pathogen entry points.

Handling and Transport Practices

Avoid dropping or rough handling to prevent bruising and splitting. Packing in ventilated, shaded crates reduces temperature spikes and mechanical injuries. Prompt field-to-cooling transfer is essential to reduce respiration and prevent wilt.

Pre-Cooling, Washing & Curing

Hydrocooling and Forced-Air Cooling

Rapid removal of field heat via hydrocooling or forced-air systems significantly slows respiration and moisture loss, preserving crispness and sugars.

Sanitizing Washes

Washing helps remove debris and microbial load but must be carefully managed to avoid periderm damage. Combining chlorine and ozonation followed by *Lactobacillus plantarum* treatment has extended shelf life to six days at ambient conditions compared to two days for untreated carrots.

Curing for Wound Healing

Post-harvest curing under moderate temperature (12–15 °C) and high humidity (90–95 %) allows periderm repair, reducing dehydration and decay during storage.

Storage Conditions & Shelf Life

Optimal Storage Parameters

Maintaining 0–1 °C and 98–100 % relative humidity preserves mature carrots for 7–9 months, while immature carrots last 4–6 weeks. Bunched carrots (with tops) typically survive only 10–14 days even under ideal conditions.

Physiological and Microbial Disorders

Common issues include:

Bitterness: induced by exposure to ethylene as low as 0.5 ppm, resulting in isocoumarin formation

White blush and browning: from dehydration or enzymatic oxidation in fresh-cut roots

Soft rot: caused by *Erwinia*, *Botrytis*, *Sclerotinia*, mitigated primarily via sanitary handling and temperature control

Hypoxia and Controlled Atmosphere Limitations

Controlled atmosphere storage is ineffective or potentially harmful for carrots: elevated CO₂ (>5 %) or low O₂ (<3 %) increases microbial spoilage and physiological stress .

Packaging & Coating Innovations

Edible Coatings and Films

Biopolymer-based coatings (e.g., chitosan, glycerol, casein) reduce dehydration and oxidation, acting like a semi-permeable barrier that slows respiration and microbial growth. These can carry antioxidants or antimicrobials to further extend shelf life.

Modified Atmosphere Packaging (MAP)

MAP for fresh-cut or baby carrots (e.g., 5% O₂, 10% CO₂, 85% N₂) controls microbial growth and preserves texture for up to three weeks under cold storage, though β -carotene degradation may still occur in some atmospheres.

Choice of Packaging Material

Use of LDPE films in conjunction with temperature control (e.g., chlorine-treated roots at 4 °C) maintained good sensory, moisture, and phenolic qualities up to 30 days.

Drying & Value-Added Processing

Drying Technologies

Recent evaluations suggest spray drying, freeze drying, microwave, infrared, and hydro-conductive methods each balance energy efficiency, nutrient retention, and drying rates differently. Conductive hydro methods offer high-quality retention at moderate cost, though still emerging in scale. Hot air-assisted radio-frequency (HA-RF) reduces drying time by over 50% compared to conventional hot-air drying, while better preserving color and vitamin C.

Juice, Powder, and Pomace Utilization

Carrot pomace is nutrient-dense (contains over 50% of original β -carotene) and can be dehydrated and powdered for incorporation into snacks, bakery goods, or beverages, enhancing functional food potential.

Automation, Sensing & Quality Control

Machine Vision for Sorting

Real-time image processing systems classify and grade carrots based on defects. Reported classification accuracy ranges from 80%–100% using conveyor-camera setups.

Emerging Sensor Technologies

Thermal imaging allows non-contact monitoring of temperature gradients during cooling or storage—helping prevent spoilage hotspots and extend shelf life. Machine learning systems are also under study for defect detection and internal quality assessment.

Traditional and Low-Cost Storage Methods

In areas lacking refrigeration, storing unwashed carrots in moist sand or soil inside cool pits or clay pots at low ambient temperatures can preserve roots for several months. Carrots with tops removed and packed in sand showed minimal quality loss when kept in cool dry conditions. Zero-energy cooling chambers using evaporative cooling also provide affordable storage solutions in rural and peri-urban regions.

Challenges & Future Recommendations

Infrastructure Limitations: Many smallholder farmers lack access to reliable cold storage, clean water for washing, and hygienic pack-houses.

Technology Adaptation: Need for low-cost, scalable packaging and sorting innovations appropriate for local contexts.

Nutrient Retention: Strategies to maintain β -carotene and vitamin C during long storage and processing require optimization.

Ethylene Control: Ensuring carrots are stored apart from ethylene-producing crops and using inhibitors like 1-MCP may reduce bitterness.

Integrative Protocols: Full-chain management—from cultivar and agronomy through harvest, storage, transport, and processing—should be context-specific and farmer-friendly.

Further Research: Trials assessing combined treatments (e.g., coatings plus microbial wash) under local climatic conditions, and pilot studies on novel drying or automation methods to evaluate cost-benefit and scalability.

Conclusion

Effective post-harvest management and processing of carrot integrate gentle harvesting, rapid cooling, controlled storage conditions, treatments (chemical, biological, physical), and value-addition through drying or juicing. While high-tech methods such as MAP, HA-RF drying, and machine vision sorting offer significant benefits, low-tech alternatives like sand storage or solar drying remain vital for many farmers. Focusing on accessible, nutrient-preserving, and affordable approaches ensures sustainability and resilience in carrot value chains—supporting food security, reducing waste, and generating additional income.