

VEGETABLES POSTHARVEST

Simple techniques for increased income and market



AVRDC

The World Vegetable Center



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Simple techniques for increased income and market

Second Edition

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AVRDC-The World Vegetable Center is the leading international nonprofit organization committed to alleviating poverty and malnutrition in the developing world through the increased production and consumption of safe vegetables.

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GTZ-Regional Economic Development (RED) Program is a Cambodian development program funded by the German Federal Ministry for Economic Cooperation and Development, aimed at promoting rural economic development, including the competitiveness of local vegetables and fruits, through a market driven approach to improving the participation of rural poor in the value-added created on Siem Reap's markets and building capacity to solve bottlenecks from production to consumption.

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Importance of vegetables postharvest

- Vegetables are high income and nutritious food crops.
- Postharvest is a critical stage where product saleability and income are being assured.
- Product saleability depends on quality developed during production and enhanced postharvest.

Postharvest loss

- Vegetable losses are high (9-25% of production) due to lack of postharvest techniques and facilities.



Improper packing and washing



Improper transport



Leaf breakage and crushing



Fruit cracking and rotting

- Lack of postharvest options has led to total loss of production.
- Postharvest loss is usually absorbed by farmers as reduced farm-gate price and consumers as increased purchase price.

Reducing postharvest loss

- Technological and marketing options reduce postharvest loss and increase income and market opportunities.



Mr. Pho Pich, farmer from Kandal, employed AVRDC-improved tomato varieties, production and postharvest, avoided losses (previously 10kg/200kg basket), and doubled his yearly income.



Mr. Mao Sorn, farmer from Kampong Speu, participated in Peri-urban Agricultural Center-led organic lettuce supply chain for supermarkets and earned four times more than that in traditional supply chain.

Knowing the produce

- This is crucial to identifying proper postharvest interventions.
- Harvested vegetables are living, i.e. they respire, lose water, produce ethylene that promotes senescence, and react to the environment (e.g. when it's hot, above processes increase).
- Vegetables are food to microorganisms causing product spoilage and human illness (e.g. *Escherichia coli*, *Salmonella*).



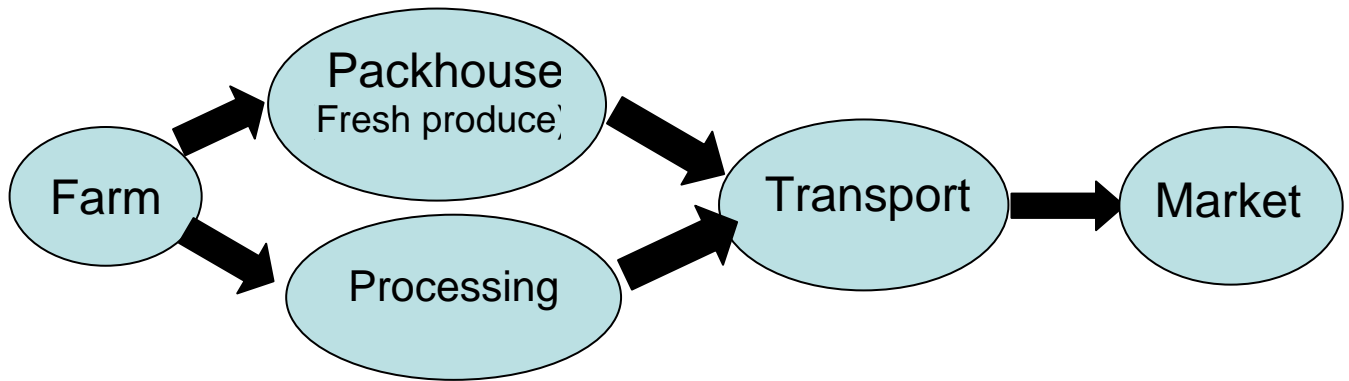
Major causes of quality loss: overripening, yellowing, shriveling and/or rotting in tomato, chili, yardlong bean, bitter melon, cucumber and eggplant; wilting, yellowing and/or rotting in Chinese kale; bacterial soft rot and wilting of outer leaves in cabbage

Knowing market requirements

- This ensures product disposal at the right time and at the right price but at the right quality.
- Quality is the composite of product characteristics that impart value to consumers. Appearance quality is always important. Internal quality (e.g. flavor).also determines repeat purchases.
- Safety is another quality attribute increasingly demanded by consumers. Food safety programs (e.g. Good Agricultural Practices or GAP) should cater to market needs.

Integrating postharvest techniques

- Postharvest techniques are integrated from farm to market.



General postharvest stages for vegetables.

- Postharvest techniques at each stage:
 - *Farm: Harvesting and field handling techniques*
 - *Packhouse: Cleaning, sorting/grading, sanitizing, microbial control, packaging, cooling and storage techniques*
 - *Transport: Loading/unloading, stacking and product protection techniques*
 - *Market: Re-sorting, re-packing, and storage techniques*
 - *Processing: Drying, sauce production, and fermentation*

Harvesting and field handling

- Postharvest begins where production ends, i.e. at harvest.

Harvest maturity

- Quality cannot be improved after harvest. Produce must be harvested at optimum maturity.



Vegetables harvested too old or too young do not keep long.



Tomato and chili are harvested based on red color. For far markets and long shelf life, tomato is harvested mature-green (full size, shiny, seeds not cut when fruit is sliced) or less red but firm. Chili can be harvested green for specific purpose or market but green fruit will not ripen normally.



Bitter gourd, cucumber, eggplant and yardlong bean are harvested when young and tender but of desired size for optimum yield. Overmaturity is indicated by yellowing in bitter gourd, cucumber and eggplant, hardness in eggplant, and prominent seed bulging in yardlong bean.

Mature cabbage head is compact and firm (by hand pressure); puffy head is immature while cracking indicates overmaturity. Chinese kale is harvested when full size but still young. Overmature kale has tough leaves and bitter taste.



Time of harvesting

- Harvest at cooler times of the day to minimize product heat and increase work efficiency of pickers.

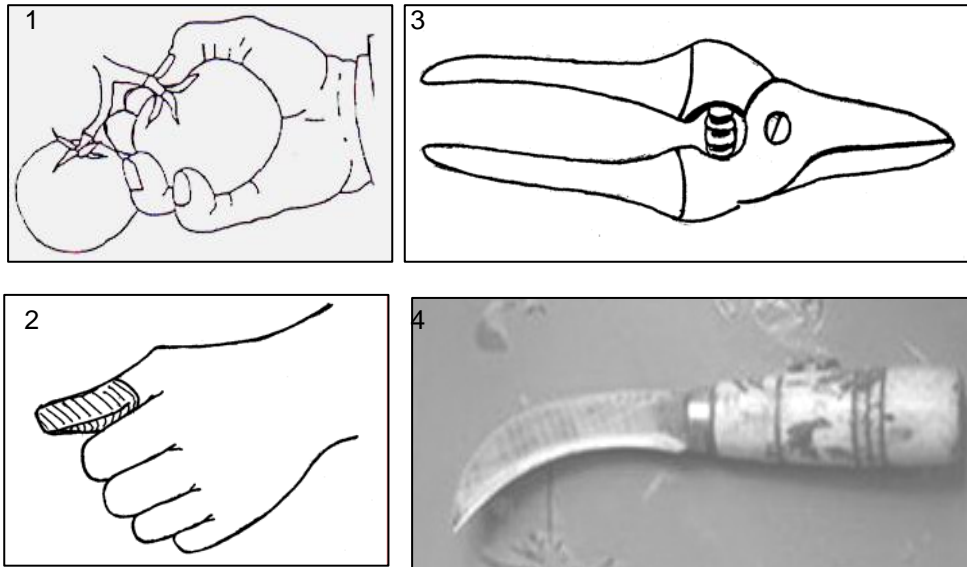


Produce harvested when the sun is up has high temperature which increases quality loss; so, allow them to dissipate heat under shade.

- Carefully harvest in early morning when plants are brittle and prone to damage.
- Do not harvest during or just after rain as wet conditions favor product spoilage. If not, washing and drying must be done.

Harvesting method

- Carefully harvest produce to minimize physical injury and preserve quality.



Handpicking (1) with nipper (2), clipper (3) or scissors, and knife (4) minimizes damage. Avoid pulling fruit to prevent removal of stem end and damage of plant and fruit for subsequent harvest. Cabbage and Chinese kale are cut with knife rather than twisted or snapped which leads to uneven cut and stalk length.



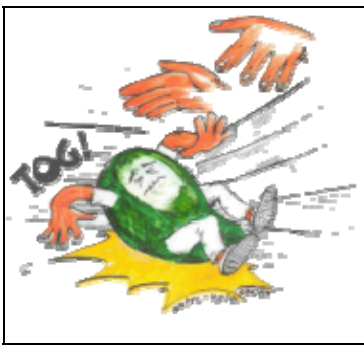
Use smooth-surfaced and small harvest containers. Pickers must wear protective clothing to avoid skin burn, irritation or allergy caused by chili oil or plant hairs (tomato, cucumber, eggplant).

Field handling

- Proper implements and care in handling produce from field to packhouse reduce damage and preserve quality.
- Sorting and packing (packinghouse operations), and loading to vehicle for transport to market can be done in the field.



Plastic crates are more advisable. For containers with rough surfaces (bamboo basket), use liners such as banana leaves or newsprint.



Avoid dropping produce or containers of produce, exposure to sunlight, and contact with soil which is a source of spoilage and human pathogens.



Field handling operations from hauling and pooling harvested produce to sorting, packing, weighing, and loading to vehicle for transport to market.

Packinghouse operations

- Activities to prepare produce for markets; include cleaning, sorting/grading, commodity treatments, and packing.

Packinghouse

- Facility for the various preparatory activities.



Simple packinghouse for tomato and cabbage for sorting and packing



Ground floor of typical rural house used as packinghouse area



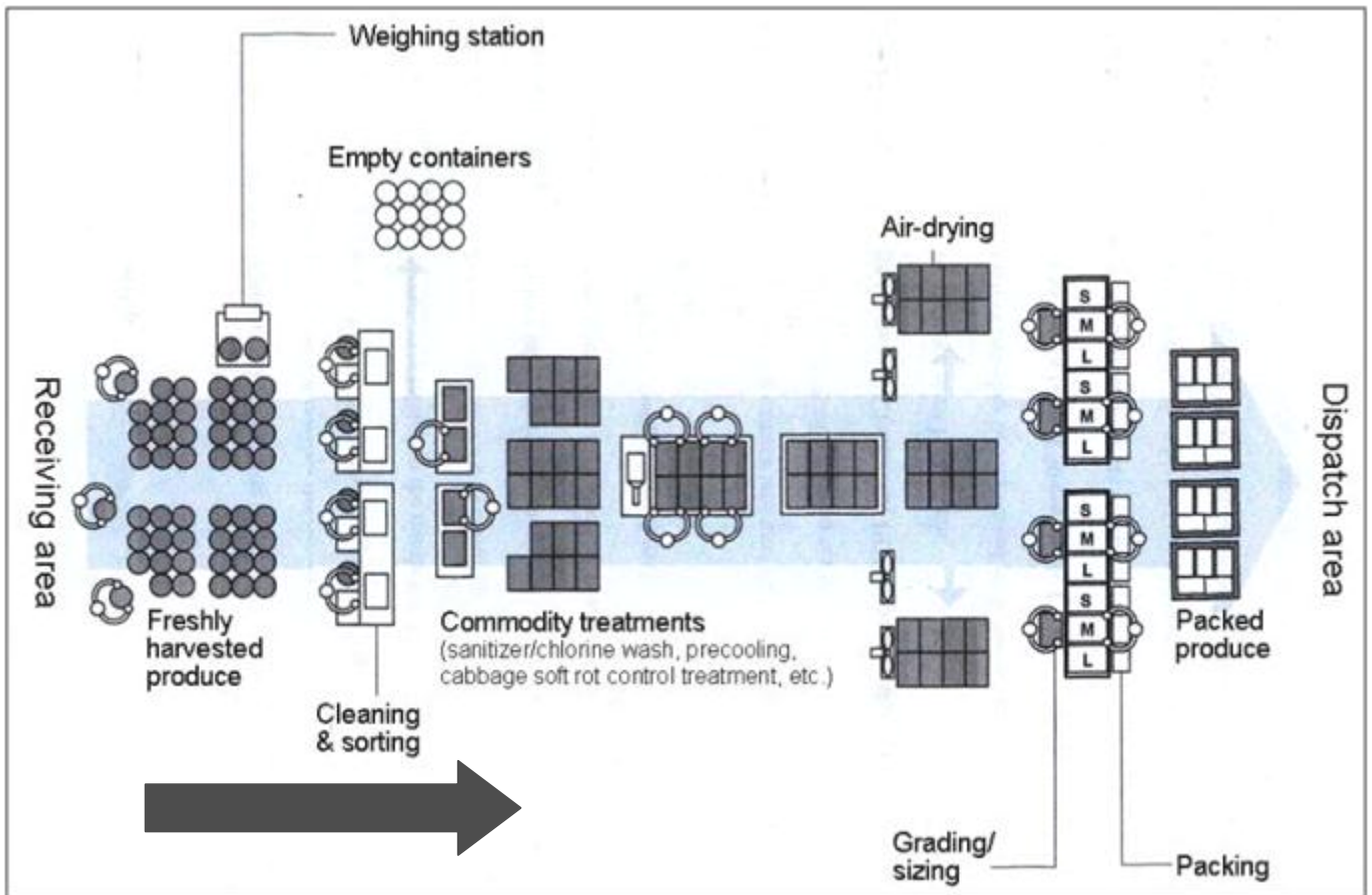
Specialized modern packinghouse



Mobile packinghouse

Activity flow

- Packinghouse operations and flow vary with type of produce and market.



- Tomato, chili, cucumber, bitter gourd and yardlong bean: cleaning-sorting-chlorine wash-airdrying-grading-packing
- Eggplant: cleaning-sorting-chlorine wash-airdrying-packing
- Cabbages and Chinese kale: cleaning-sorting-bacterial soft rot control or chlorine wash-airdrying-sizing-packing



Packinghouse activities for cabbages for supermarkets: produce arrival recording-wrapper leaf removal, butt trimming and lime application for soft rot control-plastic film packing-crating-precooling and storage

Cleaning

- Clean produce by:
 - *trimming fruit stem of eggplant and stem end of cabbage and Chinese kale*
 - *removing wrapper leaves except for 3-4 for protection in cabbage and of damaged and yellowed leaves in Chinese kale*
 - *wiping tomato, bitter melon, cucumber, and eggplant with clean soft cloth*
 - *washing to remove adhering soil and other debris.*



Avoid contact of produce with soil in the packinghouse. Use ground cover and raised table.

- While cleaning, sorting can be done to cull out damaged, diseased, off-shaped and off-sized produce.

Sorting/Grading

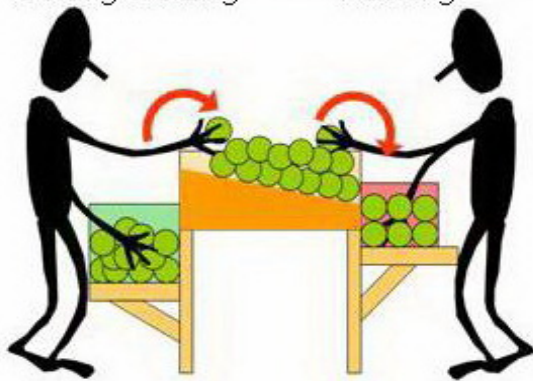
- Sorting/grading preserves produce quality by preventing microbial contamination and ethylene effects, facilitates marketing, and increases income by 40-60%.
- Sorted produce is classified according to grades or classes based on size and maturity as dictated by markets.
- Sorters/graders must be skillful. Provide adequate lighting, work breaks, and proper sorting aids.



Sorting & sizing



Packing



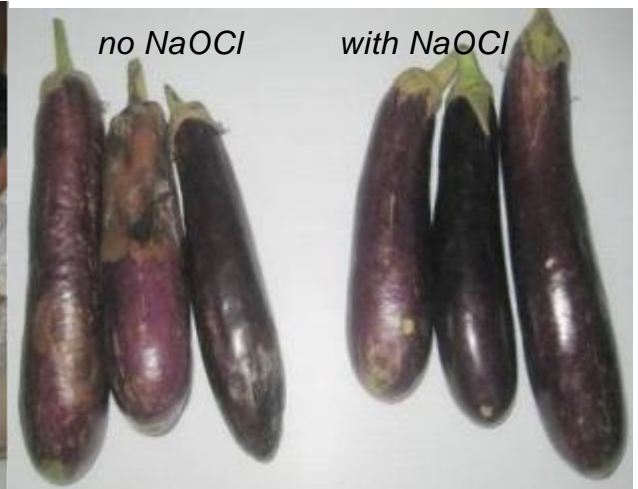
Simple sorting tables and designs for vegetables

Commodity treatments

- Chlorine wash – Washing in 100-200 ppm chlorine (mixing 4-8 tablespoons of commercial bleach, 5.25% sodium hypochlorite or NaOCl per gallon of water) for 1-3 minutes sanitizes produce and could minimize microbial decay in eggplant.



Washing with chlorinated water



Decay reduction with NaOCl wash

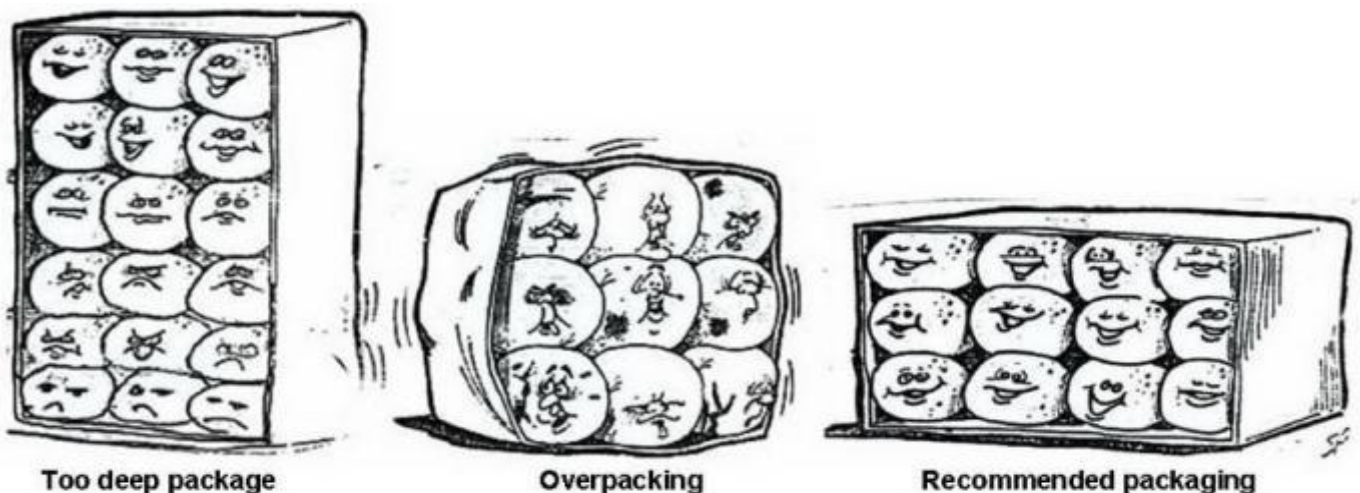
- Bicarbonate wash – In tomato, washing in 2% bicarbonate (20 grams baking soda per liter of water) could reduce storage rot by 4-33%, with net return of 0.26-0.40 USD per kg fruit.
- Cabbage soft rot control – Bacterial soft rot, the most serious problem in hot-humid climates, could be reduced by applying 10% alum (10 grams alum in 100 ml water), lime paste (mixing lime powder and water at 1:1) or guava leaf extract (mixing pure extract and water at 1:1) on the butt end of cabbage by 24-37%, with net return of 0.09-0.15 USD per kg produce.



Applying lime, alum or guava leaf extract to control soft rot.

Packaging

- Main packinghouse operation.
- It should protect produce from damage and serve as an effective handling unit.



- Vegetable packaging practices and simple innovations:



Bamboo baskets; plastic basket and crates; wooden crates with inner cardboard sides and collapsible type; carton and foam boxes



Container liners-fresh banana leaves, newsprint

Protective packaging: use of liners and cushion (newsprint), individual wraps, vents in carton box to minimize heat buildup, strapping



Individual wraps-newsprint, paper, stretchable foam cup

- Palletization or unitized handling reduces the number of times individual container is handled and minimize product damage.



- Other protective packaging measures:
 - *Use clean containers*
 - *If manual handling, use containers with capacity (e.g. <40 kg) that can be easily handled by an average person.*
 - *Fill package to capacity. Do not underpack (more vibration damage) or overpack (more compression damage).*
 - *Pack fruit of only one maturity per container.*
 - *Immobilize produce in the container. Gently shake the container now and then to permit filling up of spaces.*
 - *Secure the package by proper binding or strapping.*
 - *Pack and stack in a cool place.*
 - *Observe care during packing and handling of packages.*
- Use of 25-kg capacity polystyrene crate with shredded paper could reduce damage of tomatoes by 11-18% compared to carton box, resulting to 0.02-0.05 USD/kg net return.

Cooling and storage

- Cooling is the foundation of produce quality protection as it slows physiological processes and microbial growth.
- Every degree of reduction from ambient temperature increases storage life. So, every form of cooling is beneficial even if not optimum (e.g. avoiding sun exposure, harvesting at cooler times of the day, or using the cool night air).
- Cooling and storage add value to produce. So, use only good quality produce and manage temperature properly.

Precooling

- Rapid removal of product heat; usually used with cold storage.
- Hydrocooling (dipping in cold water) alone or together with ice packing can be done without use of expensive equipment.



Simple hydrocooler for vegetables and fruit developed at FAVRI, Vietnam, and its effect on reducing tomato chill injury (brown spots) in 10°C storage.



Ice packing of leafy vegetables in Laos



Ice bottle making

Ice bottles



Ice packing and ice bottle techniques for vegetable storage and transport, reducing temperature to 20-25°C from 35-40°C in packs of produce sealed in the afternoon and transported the following morning.

Cold storage

- If available, use refrigerated facility, the most effective method in preserving produce quality, but use it with care:
- Tropical produce (tomato, chili, bitter melon, cucumber, eggplant, yardlong bean) is chill-injured below recommended temperature. Injury is hastened at low relative humidity (RH).
- Recommendation: cucumber, tomato-10-13°C, 90-95% RH; chili-10°C, 85-90% RH; bitter melon-12-13°C, 85-90% RH; eggplant, yardlong bean-12-15°C, 90-95% RH; cabbage-0-3.5°C, 95-98% RH; Chinese kale-8-10°C, 95-98% RH.



Cold room and stacking containers of produce for adequate air circulation

- Consider the temperature, RH, and ethylene production and sensitivity of different produce when stored together.

Evaporative cooling storage

- Low-cost cooling by evaporation of water in vicinity of produce. Decrease in temperature is small, 1-6°C lower than ambient, but RH increases to more than 90%, making it effective in reducing moisture loss (weight loss).
- Simple techniques – sprinkling/wetting with water, evaporative cooler (EC) structures for short-term storage



Brick-walled EC 4.5x2.5x0.6 m in length, width & height, 15-20 cm double wall with moist sand



Box-type EC 1.3x0.9x2.0 m in L, W, H, with moist jute sack

- Brick-walled and box-type EC reduce weight loss of tomato, chili, bitter gourd, cucumber, eggplant, yardlong bean, cabbage and Chinese kale by at least two-fold compared to open storage, resulting to 0.18-0.33 USD/kg produce net gain.

Modified atmosphere packaging and storage

- Packaging or storage in modified atmosphere (MA), usually of lower oxygen and higher carbon dioxide levels than in air (21% O₂ and 0.03% CO₂), is done by sealing produce in plastic film which also creates a humid condition.

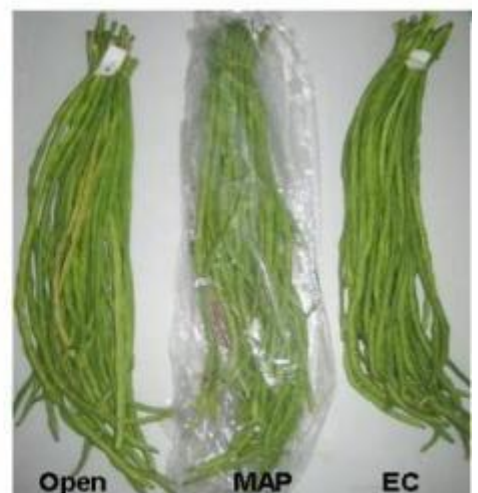


Commercially available MA films for vegetable packaging and storage



MA film for packing specific product volume or as package liner, wrap, and cover or shroud of pallets. For packaging, it must be used with rigid container as it cannot provide sufficient protection from damage.

- Holding in 25 micron-thick low density polyethylene or poly-propylene films for 3-10 days reduce weight loss by more than four-fold and increase net gain by 0.21-0.70 USD/kg produce.



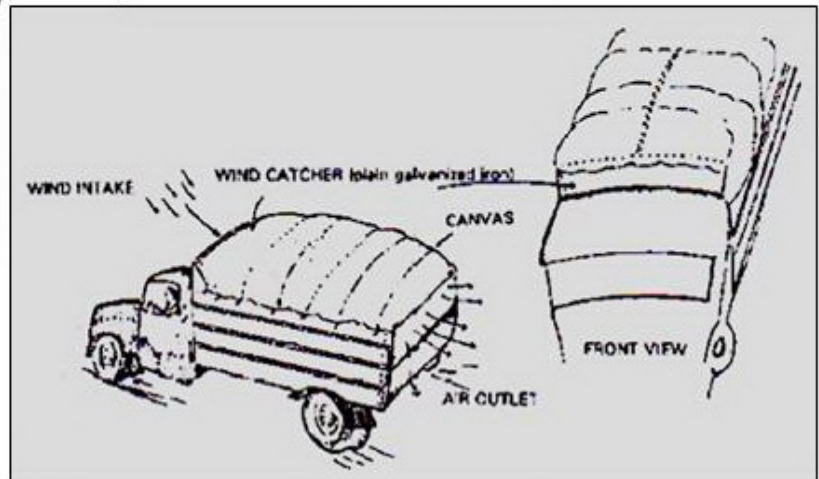
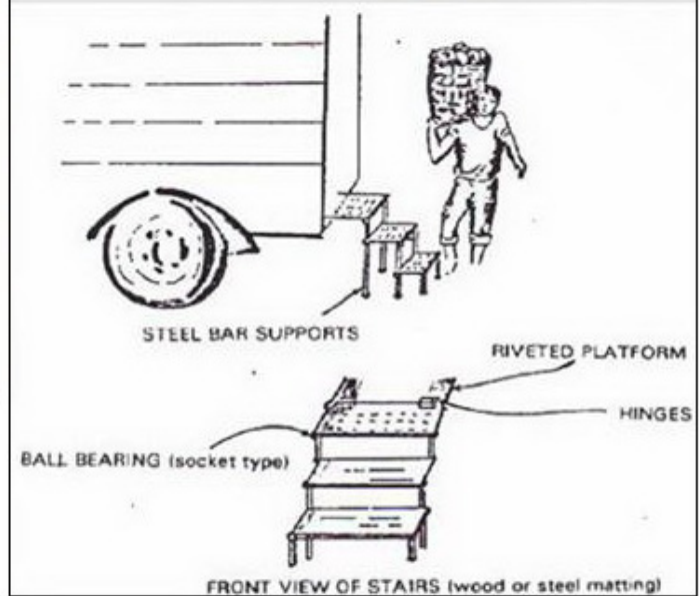
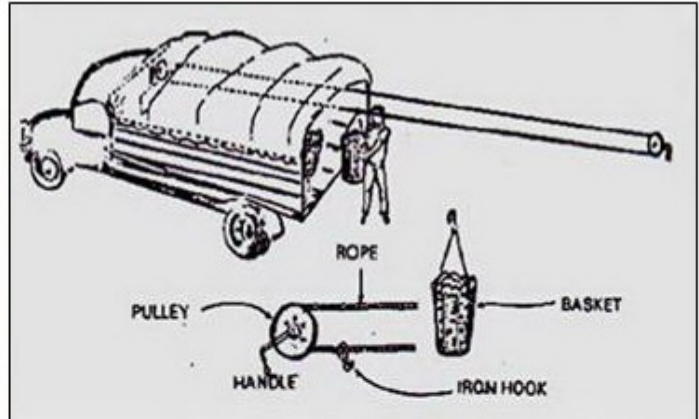
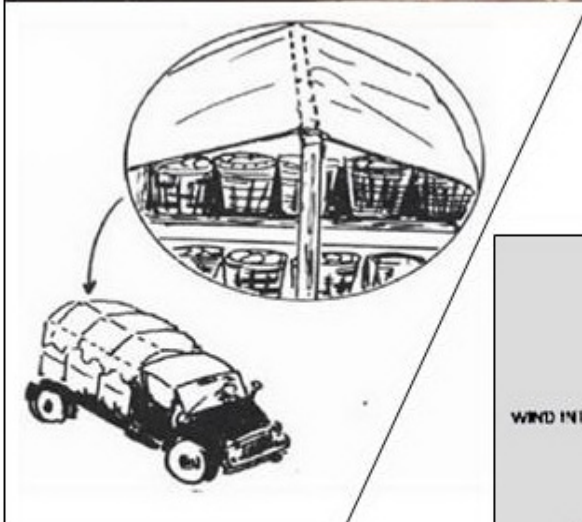
MA packaging retards tomato ripening and yardlong bean yellowing and reduce fruit shriveling and leaf wilting. Do not provide film holes for Chinese kale, bitter gourd and cucumber because yellowing is favored.

Transport

One of the most critical due to high product loss as a result of poor transport conditions, rough handling, and delays.

- If available, use refrigerated transport (like cold storage).
- In non-refrigerated transport, evaporative cooling and MA techniques can be applied.





Transport measures to minimize losses: A - canopied truck with cover from sun, rain or strong wind (canvass, curtain) and wooden separator between layers of containers; B - improvised conveyer and staircase to ease loading and unloading; C - ventilation system to minimize heat build-up in load.

- Other measures – immobilize stacks of packages by bracing and/or strapping; careful handling of packages; air suspension of trucks to reduce road shock and vibration.

Market handling - wholesale and retail

- Operation at destination markets to provide customers with best possible quality of produce.



Vegetable wholesale market, Thalaad Thai



Traditional retail outlet in public market



Vegetables retail in Ortokor market, Bangkok, Thailand

Operation

- Unload packages of produce under cover/shade, observing careful handling to minimize physical damage.



Packages unloaded under shade/cover



Careful handling while loading/unloading



Re-cleaning by trimming and washing



Re-sorting



Re-packing



Weighing and display

- Re-cleaning, washing with chlorinated water since clean vegetables are more appealing to buyers.
- Re-sorting, re-grading, necessary for vegetables of non-uniform quality, e.g. mixed maturities, partially diseased or damaged. Done to ensure quality, also for display.
- Re-packing, in wholesale/retail markets, re-sorted produce is packed into volumes/sizes more suitable for customers.



Re-trimming and sorting in retail market



Re-packing of fresh vegetable in retail outlet

- Handle and display vegetables under cover/shade.
- Spray leafy vegetables with water to avoid excessive moisture loss

Sanitation and hygiene



The improper sanitation display of vegetable traditional retailing in wet market

- Properly dispose of spoiled/rotten produce to improve presentation and extend shelflife of displayed produce.
- Clean and sanitize packing/storage facilities, preparation areas and display bins with 200 ppm chlorine water.
- Display produce packed in plastic bags. Use clean canvas or mats to cover the ground. For open produce use baskets, crates, trays or bins.

- Personal hygiene of seller and prevention of direct contact with animals (wet markets) should be considered.



Hygienic display of produce at wholesale markets



Hygienic display of produce at retail market,



Cutting large vegetables showing internal quality

- Apart from display purposes, cutting large vegetables into portions should be avoided. Cuts should be covered by cellophane wrapper to ensure hygiene.

Display

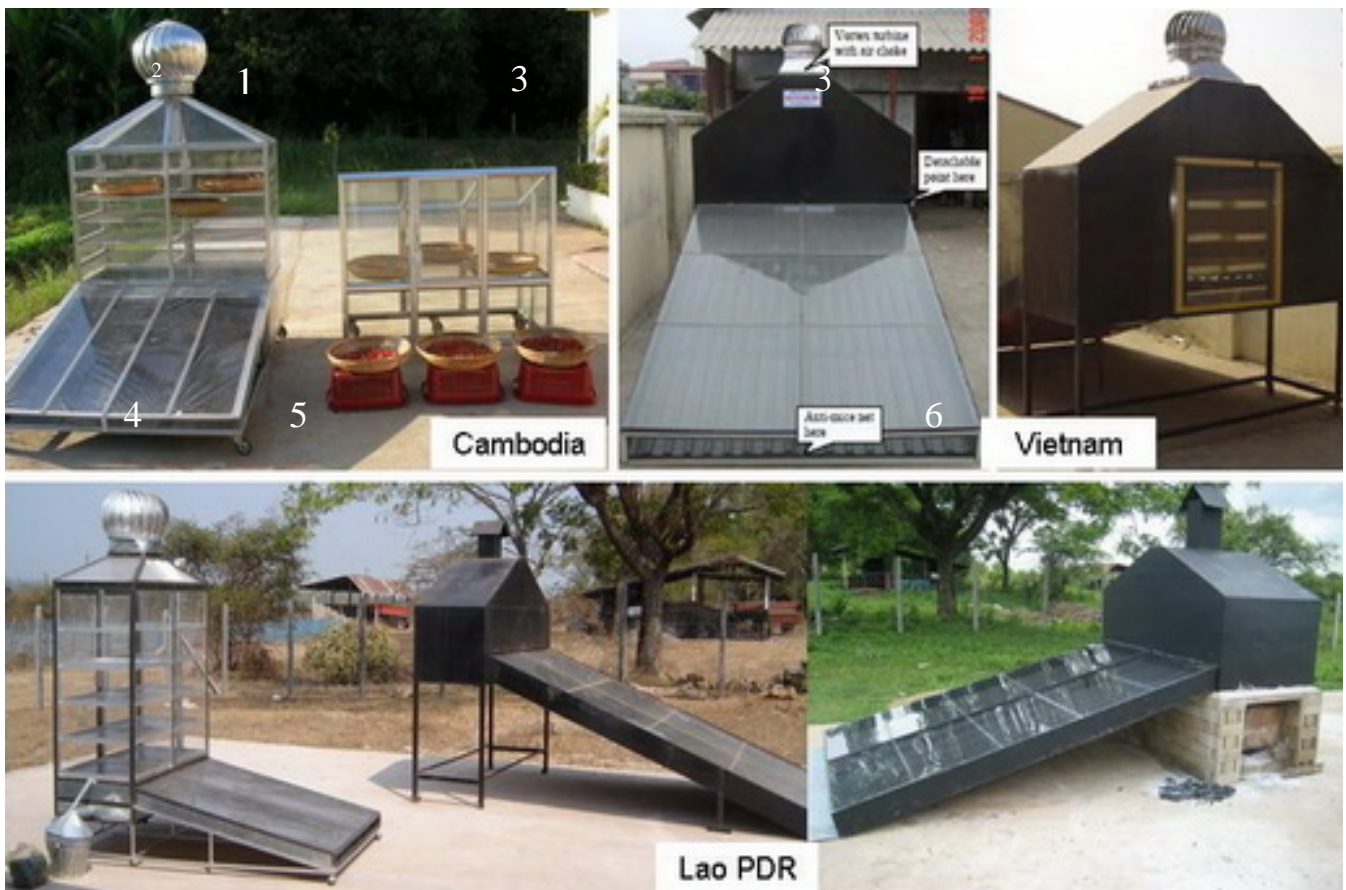
- Main factors to be considered when selecting a location for retailing are good visibility, accessibility and proximity.
- Refrigerated displays are recommended for highly perishable products.
- Ethylene producing and ethylene sensitive products are best separated in storage or display shelves to avoid untimely ripening and deterioration of sensitive fresh vegetables.

Processing

- Processing stabilizes and diversifies food supplies; extends availability of produce beyond the growing season.
- Processed products are more stable, have improved digestibility, and permit great diet diversity.

Producing dried product

- Drying – simplest processing method; commonly done by sundrying which is slow, weather-dependent and non-hygienic for being subject to microbial contamination and foreign debris.
- Simple solar dryers – more rapid and hygienic drying.



Cabinet-type solar dryer (1); dryers with solar collector & drying chamber made of plastic sheet (2,4) or glass and GI sheet (3,5,6), and with artificial heating chamber for drying during cloudy/rainy days (6)

- Solar dryers can dry chili and cabbage to $\leq 10\%$ moisture at least twice shorter than sundrying. For chili, hot water dip (65°C water for 3 min) improves color of dried product.



Cabbage drying: Heads are washed, shredded, mixed with 5% salt, fermented overnight, and spread in the drying chamber. Drying to $\leq 10\%$ moisture content could take only one day while sundrying, 2-3 days.

- Dried product is sealed in thick plastic bags (e.g. 100 micron thick polypropylene or polyethylene film) to minimize moisture absorption, and stored in a cool, dark and dry place.

Producing tomato paste

- Tomato paste is a concentrated product with minimum soluble solids of 24%. If refractometer is not available, the desired soluble solids can be determined through viscosity of paste, i.e. sticky on the teaspoon and flows slowly on the paper.
- Good tomato paste is free of seeds, skin residue and other solid parts of fruit, smooth, juicy, not too sticky, without off-color and off-odor, and with microbial count of $<10^{1-3}$.
- Deep red, big-fruited varieties are more desired to facilitate removing unneeded parts and obtain the desired red color.

Producing fermented leafy vegetable

- Fermented vegetable is produced through the action of lactic acid bacteria which convert sugar to acid in the product. It has enhanced nutritional value and improved digestibility.
- Fermentation technique for cabbage and Chinese mustard could yield $>20\%$ higher income than that for the fresh-market.



1-sorting, 2-washing, 3-slicing and seed removal



4-steaming for 30 min; 5-skin removal; 6-blending/grinding; 7-preparation of other ingredients; 8-cooking with checking of soluble solids and cooling to 65°C; 9-dispensing to bottles



Tomato paste from different varieties



Tomato paste processing: Red fruit is selected, washed, sliced, removed of seeds, steamed for 30 min to facilitate skin removal, blended, concentrated by cooking, mixed with flavor ingredients, and cooled to 65°C before dispensing to sterilized plastic bottles.



Preparation of vegetable, fermentation jars and salt solution



Removing outer/defective leaves; slicing into half and trimming young shoot in Chinese mustard; washing and drying



Placing in jars at 3.5 kg sample/jar, covering with weaved bamboo slats; putting weight; adding salt solution at 5 kg/jar



Set-up during fermentation period

Fermented cabbage or mustard in glass jar or plastic pouch with preservative solution



Fermentation procedure: Produce is sorted, sliced into half (mustard) or quarters (cabbage), washed in water and air-dried, placed in jars, added with salt solution at 8% for mustard or 10% for cabbage at 1:1 ratio (e.g. 5 kg produce:5 kg salt solution), covered with slatted material with weight to submerge produce in solution, fermented for 2 days, rinsed in water, placed in sterilized plastic pouches or glass jars 300-500g capacity, added with preservative solution (mixture of 3% sugar, 5% salt, 0.4% citric acid and 0.05% sorbic acid), pasteurized in 80°C water for 10 min, and cooled to 35°C in water and then to ambient before storage.

References

- Acedo, A.L. Jr. and Weinberger, K. 2009. Postharvest management of vegetables: Training manual for trainers of small producers in Cambodia, Laos and Vietnam. AVRDC-The World Vegetable Center, Taiwan.
- Acedo, A.L. Jr. and Weinberger, K. (eds.) 2008. Economic analysis of postharvest technologies for vegetables: Proceedings of the GMS workshop, Siem Reap, Cambodia, 19-21 August 2008. AVRDC-The World Vegetable Center, Taiwan.
- Bautista, O.K. and Esguerra, E.B. (eds.) 2007. Postharvest technology for Southeast Asian perishable crops. University of the Philippines Los Banos, Laguna and Department of Agriculture, Quezon City, Philippines. 447p.
- Borarin, B. 2009. Impacts of producing fruits and vegetables for supermarkets on farming practices: Lettuce and longan case studies in Cambodia. Food and Agriculture Organization of the United Nations-Regional Office for Asia and the Pacific (FAO-RAP), Bangkok, Thailand.
- Kanlayanarat, S., Rolle, R. and Acedo, A.L. Jr. (eds.) 2009. Horticultural chain management for countries of Asia and the Pacific region: A training package. FAO-RAP Publication 2009/06. 214p.
- Weinberger, K., Genova, C. and Acedo, A.L. Jr. 2009. Postharvest training for supply chain actors in Cambodia, Laos and Vietnam: Evaluation report. AVRDC-The World Vegetable Center Research in Action No. 1. 37p.
- Weinberger, K. and Lumpkin, T.A. 2007. Diversification into horticulture and poverty reduction: A research agenda. *World Development* 35(8): 1464–1480.