World Vegetable Center

Vegetable Postharvest Training Manual

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Antonio L. Acedo Jr.
World Vegetable Center South Asia, India

Md. Atiqur Rahman
(Bangladesh translation)
Bangladesh Agricultural Research Institute

Borarin Buntong
(Khmer translation)
Royal University of Agriculture, Cambodia

Durga Mani Gautam
(Nepali translation)
Agriculture and Forestry University, Nepal

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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.

Contact: AVRDC – The World Vegetable Center
P.O. Box 42, Shanhua, Tainan 74199
TAIWAN
Tel: +886 6 583 7801
Fax: +886 6 583 0009
Email: info@worldveg.org
Web: www.avrdc.org

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Contents

I. Introduction

The training manual

- Resource material for the training of trainers (TOT) programs on postharvest management of vegetables.
- Source of information for the crop-specific and technology-specific training of end-users (TEU) programs for smallholders. TEU material can be limited to the following topics: importance of postharvest technology and crop-specific and general information on best practices and technologies.
- Platform of information that can be used to design similar training courses and as reference material for research and education under developing country setting.
- References are provided as additional sources of information. It is essential to consult new information to ensure up-to-date knowledge of latest trends and continuously adapt and improve the training materials.
- Each chapter is presented concisely in bulleted form. Most chapters are linked to practical exercises.
- The practical exercises, including on-site trainings, provide participants actual experience of the theoretical component thereby reinforcing comprehension of the training topics.
- Practical exercises can be used to develop context-appropriate hands-on training packages for small farmer-learner programs.
- Information provided in this training manual should be shortened (telegraphic wording) and more visual images (pictures, caricatures, diagrams, etc.) should be incorporated in preparing the powerpoint presentations for the lecture part of the TOT.
- Practical exercises must be carefully planned; needed materials should be prepared well in advance; and technological treatments (effects on fresh or processed product) for observation during the training should be set up at appropriate time before the training.

Scope and contents

- Postharvest: fresh produce handling and processing

- Postharvest management: best practices and simple, low-cost technologies and innovations to reduce losses, enhance quality and food safety, and improve profitability of a farm enterprise.
- Value chain approach: from production to consumption, including varieties with desired postharvest traits, farm factors, harvesting, packinghouse operations, packaging, storage, transport, processing/value addition, handling in markets and at home
- Vegetables covered:

  Global vegetables: tomato (*Solanum lycopersicun*) and chili pepper (*Capsicum sp.*)

  Traditional vegetables: eggplant (*Solanum melongena*), cauliflower (*Brassica oleracea* var *botrytis*), cabbage (round cabbage or head cabbage) (*Brassica oleracea* var *capitata*), Chinese kale (*Brassica oleracea* var. *alboglabra*), mustard greens (*Brassica juncea* var. *rugosa*)

The training program

- The training provides participants with knowledge and experience in managing vegetable value chains and integrating postharvest technologies and best practices to reduce product losses, enhance produce quality and safety, and improve value chain efficiency.
- The training has a balance of theoretical and practical (on-site training/exposure visits and hands-on exercises) aspects. It could be tailored to client's requirement.
- To draw optimum benefit from the training, it is essential to study the training manual and the application of the practical examples to future training programmes in a different context (country, region, crops, target audience, etc.).
- In preparing training materials, the literacy level, language and knowledge base of target audience must be taken into account.
- TOT is designed to produce effective teachers of technology users. Future trainers should be able to work within the time and budget resource and to mobilize resources. This is introduced in the TEU master plan workshop of the TOT.

Planning and preparing for the training

- A well-planned training course is the basis of effective information transfer. It should integrate in a balanced manner the dimensions of academic excellence, hands-on experience, tasks, discussion sessions, excursions, formal lectures and a social dimension to allow for interaction and knowledge sharing.

- Physical facilities such as the training venue should create an environment conducive to learning but should also incorporate considerations for possible shortcomings of facilities and other issues.
- Planning a training program must consider the basic principles of adult learning, incorporating adequate breaks for reflection, discussion sessions to stimulate thought and to challenge participants, and practical exercises that relate to the lectures.
- Trainers must have some knowledge of the background of the participants and their expectations. This can be done through a simple analysis, using a basic needs assessment form. The complexity of the form will depend on the composition of the group of trainees. In situations where the trainees make up a diverse audience (for example, a mix of exporters, transporters, government officials etc.) a form such as that shown in Figure I can be used.

Implementing the training

- Every effort must be made to ensure successful knowledge transfer during implementation of a training program. Attention must be given to details that can impact on the flow and quality of the program.
- Development of basic planning schedule can ensure that details are covered and any last minute changes and rushing around are avoided.
- When preparing for lectures, it is essential that visual materials be selected according to the needs of the training group. The minimum rule of thumb of one slide a minute should be used. For a 30-minute lecture, for example the speaker should ideally select 30 slides, but might be able to go comfortably up to 45.
- It is essential to understand the trainees' situation, create a caring and concerned environment, use a variety of instructional methods suitable for the audience, exhibit enthusiasm and passion for the task, and develop a positive and participatory approach within the group.
- Visual images are remembered more effectively than words and trainees prefer 'How to' and 'Hands-on' exercises. Trainees learn better and faster when given opportunities to apply, explain and practice what they have learned or when working in groups.

Figure 1 Sample form for assessing training requirements of a diverse audience.

WHAT ARE YOUR EXPECTATIONS OF THE COURSE?

Please complete the form and answer all questions

Full name and surnames: ……………………………………………………………….
Job title: …………………………………………………………………………………..
Company/institution that you work for: ………………………………………………
Contact details, e-mail: …………………………………………………………………..
Tel no: country code …… Area code ……. Number ..………………………………………
Fields of specialisation: (tick all applicable):
Horticulture …… Post-harvest technology …… Post-harvest pathology ……
Microbiology ….. Post-harvest physiology ……. Agricultural economics …..
Education …… Others ………………………………………………………………………
Fields of formal qualification:
Horticulture …… Post-harvest technology …… Post-harvest pathology ……
Microbiology ….. Post-harvest physiology ……. Agricultural economics …..
Education …… Others ……………………………………………………………………....
In which of these fields do you currently work?
Horticulture …… Post-harvest technology …… Post-harvest pathology ……
Microbiology ….. Post-harvest physiology ……. Agricultural economics …..
Education …… Others ……………………………………………………………………..…
What is your highest qualification? ……………………………………………………......
General questions:
Do you use your e-mail regularly? Yes …. No …. If yes, how often? ……………………….
Does your company have a website? Yes … No … If yes, have you visited it? Yes ... No ….
What are your expectations of this training course? ……………………………………..
…………………………………………………………………………………………….
…………………………………………………………………………………………….
What do you plan to do with this information once you return to your respective country?
………………………..…………………………………………………………
Are you involved in training? Yes … No .... If yes, for whom? …………………………
What is the trainees' level of education? …… How many attend at a time? …………
How often do you train people per year? … Do you enjoy it? Yes … Not really ………
Would you like to see more practicals in a training programme? Yes …. No ….
Why? ……………………………………………………………………………………….
What kind of practicals? …………………………………………………………………
What level do you think this course is going to be? ……..………………………………
Do you think you need a test at the end? Yes … No …. If yes, why? ……….…………
How would you like to be measured in terms of absorbing the knowledge? …………
Any suggestions for the trainer in terms of your expectations? …………………………

Evaluating the training

- Training evaluation helps to continuously improve training delivery and outcome/impact. It gives trainees an opportunity to question and to be aware of what they have learned. It also gives them confidence to apply the skills they have acquired and helps them analyze the way in which they have acquired knowledge.
- Feedback could be obtained through the use of assessment forms to rate presenters, the material presented by them, the content of their presentations, and the level of confidence with which they presented the material. A sample training evaluation instrument is given in Figure 2.
- Credit can be given for group discussion during the programme and individual participation may be acknowledged at the end of the workshop. Awarding tokens for the best participant, most vocal individual, funniest person etc. is always fun and makes the workshop memorable.
- The training can be concluded with a test or puzzle to determine the level of effective uptake. Tasks may be given and a time frame to complete the tasks could be an alternative way of assessing the knowledge uptake of participants. For trainees who are technology end-users (e.g. small farmers and other value chain actors), an assessment form to be filled up by them right after the training (Figure 3) and after 6-12 months later (Figure 4) can measure technology uptake.
- A basic databank should be developed and maintained to record the date, venue, type of training offered, number of trainees attending, their personal contact details and whether they have successfully completed the course. Keeping a databank of training programmes held can aid in the efficient logistical management of events.

Figure 2 Sample training assessment form.

Training Evaluation

Country or Name (optional):______________________ Date:____________

Aspect to evaluate	**5** excellent	**4** Very good	**3** Good	**2** Fair	**1** Poor
1. Resource persons					
Preparedness					
Communication skills					
Effectiveness in presenting the topic using available tools					
Experience in the field					
Ability to retain the concentration of the group					
Ability to stimulate discussions and interaction					
Ability to create a stimulating environment					
2. Lecture materials					
Adequacy/sufficiency for the topic					
Comprehensiveness of the content					
Structure of the presentation					
Variations in the presentation					
Effectiveness in bringing the message and concepts across					
3. Practical exercises/field visits					
Relevance to the topic					
Adequacy/sufficiency for the topic					
Organization/structure of hands-on activities					
Usefulness in enriching the lecture					
4. Overall training course					
Organization of the training					
Adequacy/sufficiency of training facilities					
Effectiveness as a 'train the trainer' course					
Practical application of the course					
Did the training meet your expectations					

5. Other impressions – please write down other feedback not covered above:

5.1. Other strong points of the training:

5.2. Other weak points of the training:

Figure 3 Sample evaluation form right after the training of end-users.

AVRDC/USAID Postharvest Project's Technology Promotion Activity
EVALUATION RIGHT AFTER THE ACTIVITY

1. Name of activity: ____
2. Date and place of activity: ____
3. Co-sponsor/co-organizer (in addition to AVRDC):____________________________________

Participant's information:

1. Name: __________________________ 2. Age:______ 3. Gender:_____ 4. Family size:_____
2. Address: ____
3. Phone/Cellphone number: ____
4. Classify yourself (one or more) by ticking appropriate box:
   □1 Input supplier □2 Farmer □3Trader/marketer □4 Processor □5 Consumer
   □6 Government employee □7 University employee □8NGO employee □9 Private enterprise
   □10 Others (please specify):_______________
5. Main source of income: ____________________ 6. Average monthly income: _____________
6. Farm area (please specify unit):
   Total farm area: __________________
   Vegetable farm area: ______________
   Tomato farm area: ________________
   Farm area of 2nd crop (Bangladesh-brinjal; Cambodia-leaf mustard; Nepal-cauliflower):___
7. Do you plan to increase the area for vegetables in the next year (Y/N): ___; if yes, specify expansion area:
   Vegetable farm area: ______________
   Tomato farm area: ________________
   Farm area of 2nd crop (Bangladesh-brinjal; Cambodia-leaf mustard; Nepal-cauliflower):_____________
8. Are you a member of a group or association (Y/N)? _____; if yes, classify and give the name:
   □1 Private enterprise (for profit):____
   □2 Farmers/Processors/Producers group:____
   □3 Water users association:____
   □4 Women's group:____
   □5 Trade and business association:____
   □6 Community based organization (CBO):_______________________________________
   □7 Others (specify):____

Overall assessment of the technology promotion activity:

□5 Excellent – excellent delivery, more practical activities (including hands-on and demonstration of techniques); all knowledge and techniques were new.
□4 Very good – very good delivery, more practical activities; more than 50% of the knowledge and techniques taught were new.
□3 Good – good delivery with more practical activities but less than 50% of the knowledge and techniques taught were new.
□2 Fair – more lecture than practical activities; less than 50% of the knowledge and techniques taught were new.
□1 Poor – only lecture, no practical activities; all knowledge and techniques taught were not new.

Other comments about the activity:

Knowledge uptake right after the technology promotion activity:

1. Did you know anything about postharvest technology/best practics before this activity (Y/N)?___

   If yes, please specify this postharvest knowledge:

   ____

   ____

2. Did you learn anything new from this activity (Y/N)? _____;

   If yes, what new knowledge did you gain (tick appropriate box and specify if possible):

   □1 Harvesting:____
   □2 Field handling: ____
   □3 Packinghouse operations (e.g. sorting, cleaning, etc.):_______________________
   □4 Packaging: ____
   □5 Storage: ____
   □6 Market handling: ____
   □7 Processing:____
   □8 Others (specify):____

3. Will you adopt the technologies and best practices you learned from this activity (Y/N)? ______

   If yes, which knowledge you will adopt:

   □1 All
   □2 Some (specify) ____
   ____

4. Can you share the knowledge to others in the next six months (Y/N)?____

   If yes, how many persons below to whom you will share the knowledge and what is their farm area?

Category	Number of persons	Farm area (specify unit)		
		All vegetables	Tomato	2nd priority crop/ country (specify)
Input supplier				
Farmers				
Processors				
Marketers (collectors, wholesalers, retailers)				
Private enterprise/ business operators				
Others (specify)				

Figure 4 Sample evaluation form after 6-12 months from training of end-users.

AVRDC/USAID Postharvest Project's Technology Promotion Activity
EVALUATION AFTER 6-12 MONTHS FROM CONDUCTING THE ACTIVITY

Our record shows that you participated in the following technology promotion activity and we would like to know about how you used the knowledge and skills gained from this activity and their outcomes.

1. Name of participant (other information in previous form): ______________________________
2. Name of activity: ____
3. Date and place of activity: ____

Use of postharvest knowledge (technologies and/or best practices)

1. Did you use the postharvest knowledge you gained from the past training (Y/N)? ______
2. If no, what is/are the reason/s? ____
3. If yes, what postharvest knowledge did you adopt? (tick appropriate box and specify):
   - □1 Harvesting: ____
   - □2 Field handling: ____
   - □3 Packinghouse operations (e.g. sorting, cleaning, etc.): _________________________
   - □4 Packaging: ____
   - □5 Storage: ____
   - □6 Market handling: ____
   - □7 Processing: ____
   - □8 Others (specify): ____
4. Will you continue to use the postharvest knowledge (Y/N)?_____
5. What is the reason for continuing (Y) or not continuing (N) using the postharvest knowledge?

   ____

Effects of using the postharvest knowledge (technologies and/or best practices)

1. What happened when you used the postharvest knowledge? (tick one or more)
   - □1 Reduced postharvest losses □2 Increased income □3 Higher price of produce
   - □4 Better product quality & shelf life □5 More markets/buyers □6 Easy to sell produce
   - □7 Increased the production (for farmers), product volume for marketing (for marketers) or product volume for processing (for processors)
   - □8 Others (specify) ____

2. In relation to your answer/s in no. 1 (reduced losses, increased income, increased price, and/or increased production or marketing volume), provide the necessary information in the following table:

VC actor/Crop	Postharvest loss (specify unit)		Production area (for farmers)		Prodn, marketing or processing volume per cycle (spec unit)		Frequency of prodn, marketing or processing per year		Unit price of produce (specify unit)	
	Before	After	Before	After	Before	After	Before	After	Before	After
A. Farmers										
Tomato										
Brinjal, mustard, cauliflower (encircle county 2nd crop)										
All vegetables										
B. Marketers (specify whether collectors, wholesalers, retailers)										
Tomato										
Brinjal, mustard, cauliflower (encircle county 2nd crop)										
All vegetables										
C. Processors										
Tomato										
Brinjal, mustard, cauliflower (encircle county 2nd crop)										
All vegetables										

'Before' means before attending the technology promotion activity; 'After' means after attending such activity.
Postharvest loss can be answered as volume loss per pack; percent loss and total loss can be computed later.
Frequency of marketing can be per week and then calculated to per month or year.

3. Did you share the postharvest knowledge to others (Y/N)?_____
If Yes, complete the following table:

Type of VC actor to whom knowledge was shared	No. of persons	Area planted to vegetables	Are they group or assn. members?*		Did they use the postharvest knowledge?	
			Yes/No	Name of group or assn.	Yes/No	If Yes, what happened?**
□1 Input supplier						
□2 Farmer/farm household						
□3Marketer (collectors, wholesalers or retailers)						
□4 Processor						
□5 Consumer						
□6 Government employee						
□7 University employee						
□8 NGO employee						
□9 Private enterprise person						
□10 Other (specify):						

**Group or association includes Private enterprise (for profit); Producers organization; Water users association; Women's group; Trade and business associations; Community based organization (CBO); Farmer's group; Consumer's association; and others (specify)*
***Possible effects are the same as in no. 1.*

4. If you have increased your income as a result of the application of the postharvest knowledge, what did it bring to your life? (tick one or more)
   - □1 Acquire more assets (specify the assets) ________________________________
   - □2 Open new business (specify the business) ________________________________
   - □3 Sent children to school
   - □4 Save more money in the bank
   - □5 Life is easier financially than before
   - □6 Others (specify) ____

II. Importance of Postharvest Management

Reducing postharvest losses

- A global agenda under the United Nations Sustainable Development Goal (SDG) 12.3 which targets 50% reduction of per capita global food waste at the retail and consumer levels and food losses along production and supply chains, including postharvest losses by 2030.
- SDG 12.3 recognizes that about one-third of food produced for human consumption is lost or wasted globally, which amounts to about 1.3 billion tons of food per year worth nearly USD one trillion. These losses account for about one-fourth of water used in agriculture, total cropland area, and total fertilizer use, and produce about 3.3 billion tons of CO_2 emissions yearly.
- In developing countries, about 65% of lost food occurs at the production, processing and postharvest stages.
- Reducing food loss and waste can save money for farmers, businesses, and households; can feed more people; and can alleviate pressure on climate, water, and land resources.
- Specifically, postharvest loss reduction can:
  - Increase market share and competitiveness of smallholders
  - Stimulate growth of agribusiness industries, such as input suppliers (e.g. packaging, processing ingredient) and logistics providers (e.g. transport, storage).
  - Generate more employment and income opportunities and stimulate the rural economy.
  - Promote gender equality asmore women are involved in postharvest and marketing operations.
  - Improve human nutrition and health
- Vegetables are high income and nutritious food crops. Reducing postharvest losses reduces poverty and food insecurity.
- Cross-cutting strategies to reduce food losses include:
  - Developing loss measurement protocol
  - Setting loss reduction targets

- Increasing investment in loss reduction in developing countries
- Supporting collaborative initiatives to reduce losses

Postharvest losses of vegetables

- Postharvest losses of vegetables are serious in developing countries due to lack of knowledge, techniques, and facilities for produce handling and processing and poor marketing systems. The corresponding loss of food and economic opportunities contributes to poverty, food insecurity and malnutrition, which mostly affect smallholders who dominate vegetable industries.
- 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.
- Postharvest losses vary with crop, location, production season, value chain, and value chain actor.
- For the major vegetables (tomato, eggplant, leaf mustard and cauliflower) in Bangladesh, Cambodia and Nepal, postharvest losses range from 19-35% of production (Figure 5). AVRDC also assessed earlier vegetable losses in three Southeast Asian countries and found an average loss of about 17% equivalent to 1.5 million metric tons worth USD 461 million annually (Figure 6).

Figure 5 Postharvest losses of vegetables in Bangladesh, Cambodia and Nepal.

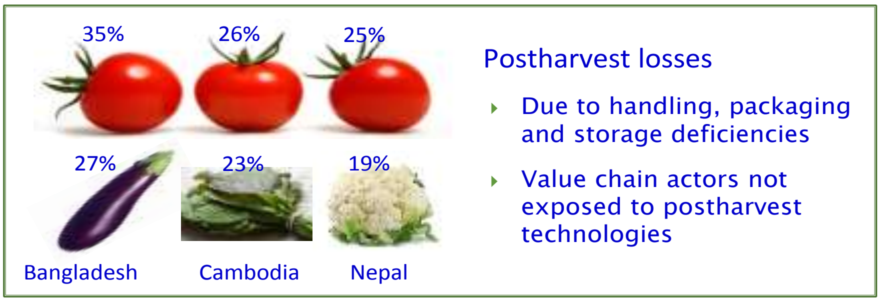
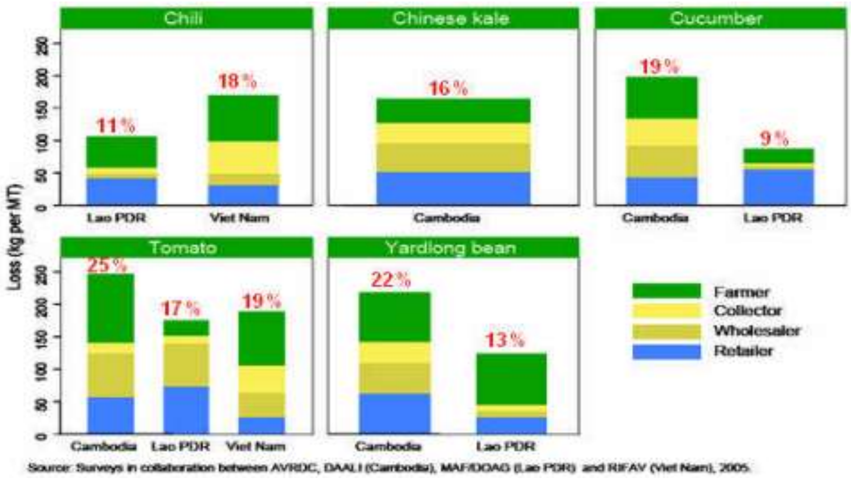


Figure 6 Postharvest losses of major vegetables in Cambodia, Laos and Vietnam.

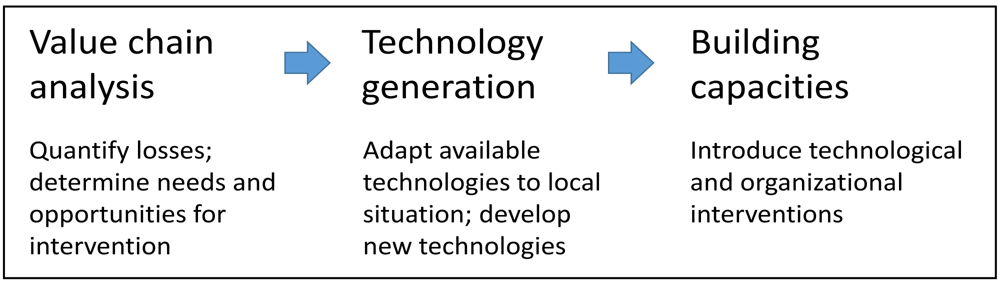


- Unseen losses are the loss of nutrients (e.g. vitamin C) and wholesomeness (e.g. pathogenic microbes and pesticide residues).
- Loss of vitamin C, which is usually used as nutritional indicator, may range from 27-100% depending on the conditions during the postharvest period. Loss of B vitamins, particularly thiamin and B6, varies from 7-70%. Carotenoids and fiber are relatively stable.
- Faulty postharvest practices, such as poor hygiene and use of contaminated wash water, provide opportunities for contamination by toxin-producing and pathogenic microorganisms.
- Food safety is a global issue and compliance to food safety assurance systems (e.g. GAP, GMP and HACCP) is a prerequisite to access high-value export markets.

Value chain approach to reducing postharvest losses

- This ensures real needs and problems are addressed and interventions fit into the system.
- In general, the approach has three components (Figure 7).
    - Value chain analysis – losses are assessed and the needs and priorities for intervention are determined.
    - Technology generation – adaptive research optimizes and suits available technologies to local condition. Research to develop new technologies can also be conducted.
    - Building capacities – technological and non-technological interventions are introduced to capacitate value chain actors for better control of quality and volume of produce and for more competitive marketing. These may include training programs, workshops, exposure visits, linking to markets, input suppliers and finance, and technical backstopping.

Figure 7 Value chain approach to reducing postharvest losses.



III. Vegetable Value Chains

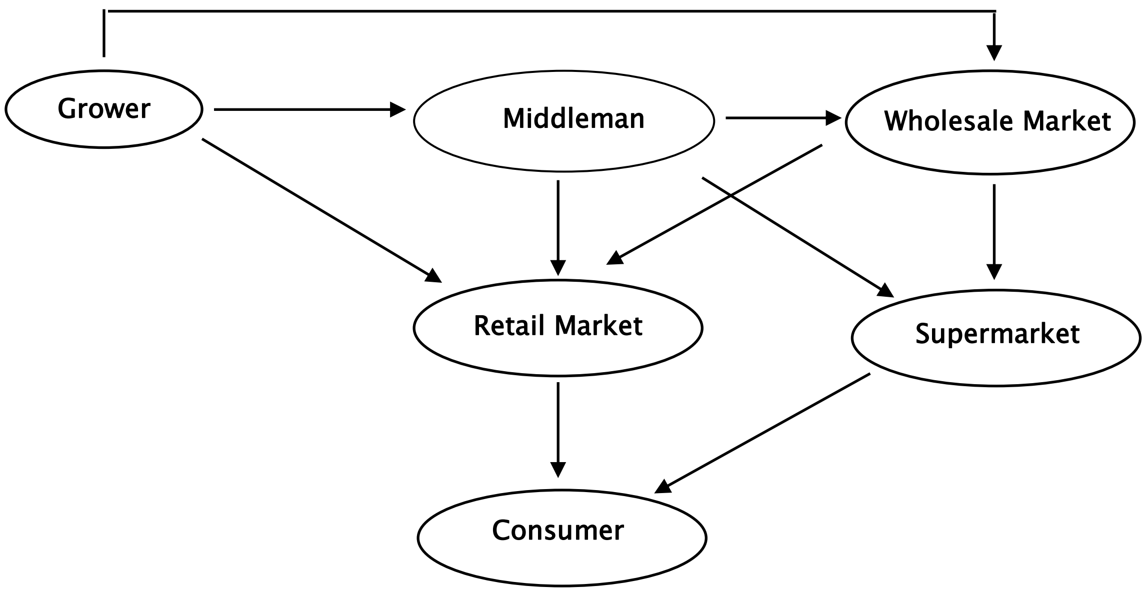
Value chain

- Chain of activities from input supply (seed, fertilizer, chemicals) through production, postharvest operations, distribution, and retail.
- Value chains vary considerably in length and complexity, depending on distance between the producer and the target market.

Traditional chain

- Traditional value chains are long and complex, involving several intermediaries with high transaction costs. Figure 8 shows a typical traditional chain for vegetables prevalent in developing countries. There are other more complex chains when vegetables are brought from one province to another involving another set of intermediaries.

Figure 8 Typical traditional chain for vegetables.



- Traditional chains are largely supply driven with little coordination. They are a low technology system usually with no temperature control and rely on selling the produce within one day after harvest. Losses of produce could be very high particularly under adverse climate.
- Traditional chains may involve both informal and formal rural and urban markets. Produce is moved from rural to urban areas through a chain of intermediaries such as assemblers and wholesalers supplying

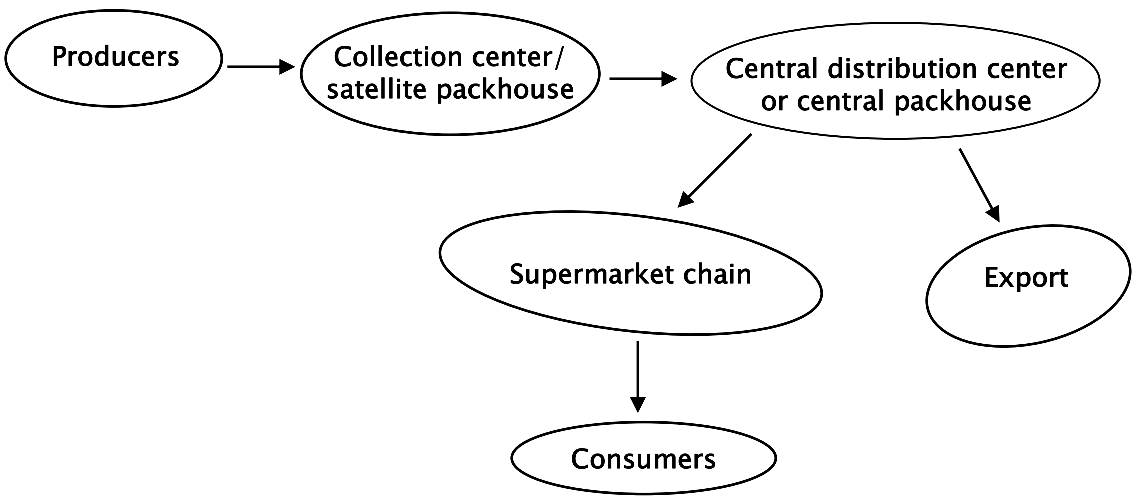
produce to urban markets and commission brokers acting on behalf of large, long-distance traders.

- Wholesale and semi-wholesale markets are located within or near to major urban centers and may be supplied by purchasing/assembly centres in rural areas or directly from farms, particularly those in peri-urban areas. Produce is supplied either by agents, traders or by farmers themselves.

Modern chain

- This is usually well coordinated and driven by consumer requirements. They evolved with the proliferation of supermarkets/hypermarkets and increase in trans-national/crossborder trade.
- Figures 9 shows a typical modern value chain.

Figure 9 Typical modern value chains.



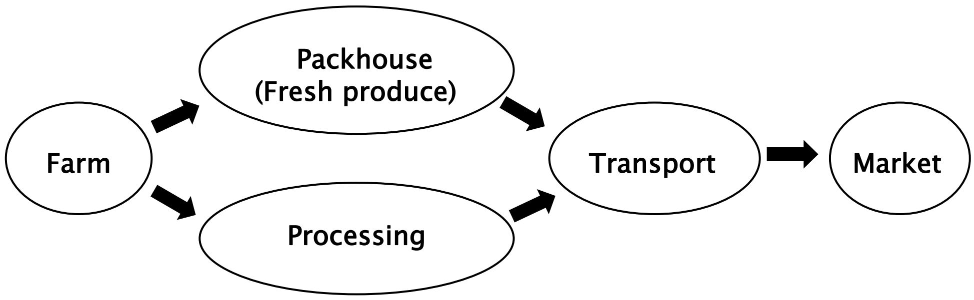
- Farmers are contracted with guaranteed price. Depending on the crop, the harvested produce is sorted and packed on farm and brought to the collection center (satellite packhouse) for quality checking, sorting, treatment, packing, pre-cooling, and cold storage. Small refrigerated trucks collect and bring the produce to the central where produce is processed and packed to a high standard of efficiency and hygiene. Low grade or excess produce is usually sent for food processing. The packed produce is transported to supermarkets in refrigerated trucks or in refrigerated container vans for export shipment. If distribution cannot be done on the same day of arrival, storage is done in a central cold room. The cold chain system is operational in both cases.

- Export chains of vegetables vary with degree of vertical coordination. *Vertically-integrated exporters* are exporters who grow produce on their own farms, arrange shipping to overseas destinations and even distribute the goods to supermarkets and wholesalers in foreign markets. Other groups of exporters are *those who consolidate produce from contract growers directly* and *those who consolidate produce procured by brokers* who in turn consolidate produce from farmers in spot market transactions or through farmer groups.

Postharvest chain

- Postharvest activities are conducted starting at the farm (harvesting and field handling), packhouse or processing plant, and during transport and marketing (Figure 10). These are separately described in later topics.

Figure 10 General chain of postharvest activities.



IV. Vegetable Quality and Food Safety

Quality

- Quality is the composite of product characteristics that impart value to the consumers.

  Low quality – produce not meeting consumer expectations

  Acceptable quality – produce satisfying consumer expectations

  High quality – produce exceeding consumer expectations

- Product salability depends on quality developed during production and enhanced postharvest.
- Consumer expectations of quality should drive production and postharvest operations. Consumers usually buy with their eyes (appearance quality) but repeat sales are determined by unseen internal quality attributes.
- Vegetables have added quality credential being rich sources of vitamins, minerals, dietary fiber and pharmaceuticals – an opportunity for promoting marketing and consumption.
- However, vegetables are often perceived to be unsafe due to the general knowledge of heavy pesticide use during production and poor hygiene and use of toxic preservatives (e.g. formaldehyde) after harvest. Exacerbating factor is the widely publicized food poisoning cases associated with consumption of fresh vegetables.

Quality components

- Appearance (visual) quality – for fruit-vegetables, it may include right maturity or color, right size and shape, glossy, and free of defects such as shriveling, spots or rots; for leafy vegetables, fresh-looking, well-formed or well-shaped, right size, right maturity, right color, turgid or not wilted, free of defects such as rots, physical damage, yellowing or wilting

  Measurement: use of rating scales (e.g. visual quality rating, color index, and defects rating) with quality and color charts (Figure 11); colorimeter or Chromameter (quantitative color); gloss meter; weighing scale; caliper (Figure 12)

Figure 11 Examples of quality grading and color charts.

Tomato quality grading

Fruit ripening stages

Green Stage 1	Breaker Stage 2	Turning Stage 3	Pink Stage 4	Light red Stage 5	Red Stage 6

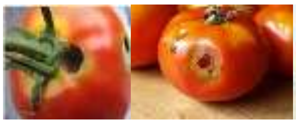
Fruit defects

Growth cracks

Deformation

Blossom-end rot

Blotchy ripening



Insect pest damage

Fruit spots

Bruising

Brinjal (eggplant) quality grading

Deformed

Bruising

Fruit borer damage

Thrips damage

Phomopsis fruit rot

Cauliflower quality grading

Good for harvest

With trimmed leaves

Bare curd

Overmature

Rust

Physical damage

Browning

Figure 12 Some instruments for quality measurement.

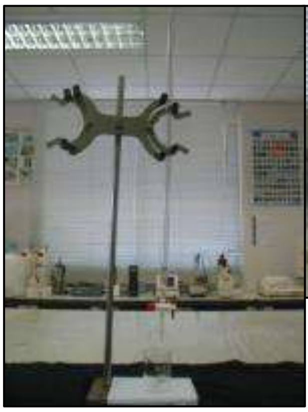
Colorimeter to quantify color

Gloss meter

Caliper (top) and weight scale (bottom) for size and weight

Penetrometer (top) and electronic texture analyzer (right)

Refractometer, analog (top) and digital (bottom)



Burette and stand for manual titration (left) and automatic titration system (top)

pH meter

Pesticide residue meter

ATP hygiene meter

DA meter for non-invasive quality evaluation

- Texture (feel) – firmness; tenderness, crunchiness, solidity or compactness (cauliflower, broccoli and cabbage),

  Measurement: penetrometer; texture analyzer; finger feel with rating scale; curd arrangement in cauliflower and broccoli

- Flavor (eating quality) – aroma, taste, sourness, spiciness

  Measurement: sensory quality evaluation by panelists using hedonic scale or descriptive scoring; refractometer for soluble solids content; titration system for titratable acidity; pH meter; differential absorbance (DA) meter for non-invasive measurement of chemical attributes and firmness

  Sensory testing is the only sure way to determine what the consumer thinks about vegetables. However, sensory evaluation is not suitable for routine use and the best way is to find objective measurements that correlate with sensory attributes.

- *Nutritional quality* – vitamins, minerals, lipids, protein, carbohydrate, phytonutrients (antioxidants and flavonoids) and dietary fibers

  Measurement: standard chemical analysis

- *Food safety (see also next topic)* – pesticide residues (most important safety issue among consumers), microbial contamination (number one food safety concern among health authorities and scientists), natural toxicants (e.g. oxalates and nitrates), natural contaminants (e.g. mycotoxins, bacterial toxins and heavy metals (e.g. lead, cadmium and mercury), and environmental pollutants

  Measurement: ATP hygiene meter or standard plating methods for microbial enumeration; pesticide residue meter; standard chemical analysis

- *Credence attributes* – additional dimension of quality that has evolved in international markets and depends on the method of production, regardless of whether the method of production has a visible or analyzable impact on the produce. Examples of credence attributes include sustainable environmental profiles or fair trade conditions.

Quality loss

- The nature of quality loss depends on the type of produce (Figure 13):

  Tomato, chili – overripening, shriveling, rots

  Eggplant – shriveling, rots

Beans, bitter gourd, cucumber – shriveling, yellowing, rots

Leaf mustard, kale and other leafy type – wilting, yellowing, rots

Cabbage, head – bacterial soft rot, wilting of outer leaves

Cauliflower – browning, bacterial soft rot, desiccation

Broccoli – yellowing, bacterial soft rot, desiccation

Figure 13 Nature of quality loss of vegetables – tomato rots, chili shriveling, bean rot, cucumber yellowing, eggplant rot, leaf mustard yellowing and cabbage soft rot.

Quality monitoring

- Grade standards are used for monitoring quality in value chains. They ensure that produce complies with buyer's requirements.
- Grade standards facilitate labelling, provide a basis for reporting on market prices, and are the legal framework used for the settlement of commercial disputes.
- Quality standards take into account many factors, such as
    - definition of the produce
    - minimum requirements (cleanliness, appearance, flavor, odor, maturity)
    - definition of different classes or grades based on quality characteristics, acceptable product size, presentation of the produce in terms of their uniformity and packaging, information on the package such as origin of the produce, grade, size, storage conditions and methods of handling, and approved pesticides and maximum residue levels (MRL).

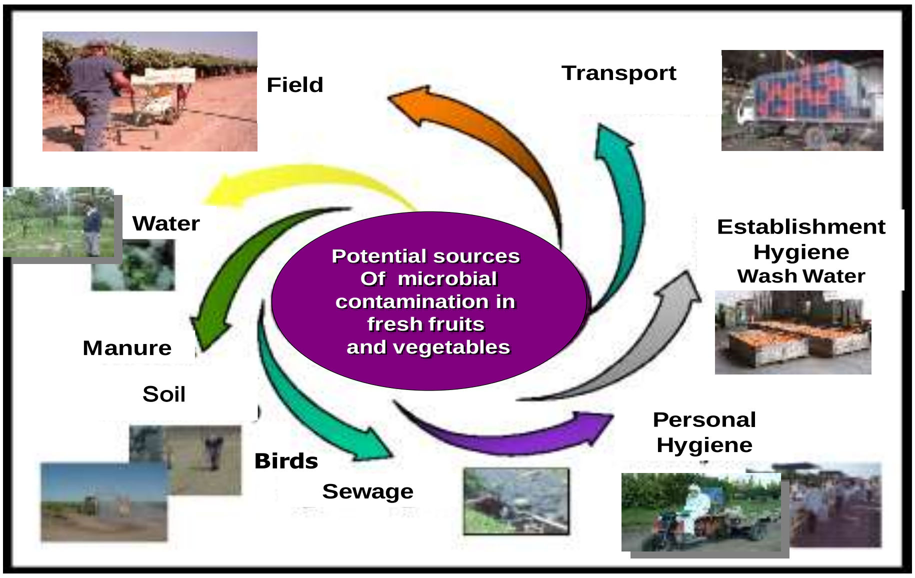
Food safety

- Assurance that food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use.
- Assuring food safety is for consumer protection, a universal mandate.

Food safety assurance

- Measures taken during production and postharvest (handling, storage and distribution) to ensure that product consumption does not represent a risk to human health.
- Expands market access and market confidence.
- Hazard is a biological, chemical or physical agent in food with the potential to cause an adverse health effect.
- Risk is the probability of a hazard occurring.
- Produce is vulnerable to hazards at every step of the chain.
- *Biological hazards* include pathogenic organisms (*e.g. Eschirichia coli* and *Salmonella)* and spoilage organisms, insect pests, animals etc.
- Sometimes, pathogenic microbial load may be insufficient to cause product decay but may be enough to cause human illness.
- Produce that appears to be perfect could be microbiologically contaminated and thus could represent a risk to consumer health. Figure 14 shows the sources of microbial contamination of vegetables.

Figure 14 Potential sources of microbial contamination of fresh vegetables.



- *Chemical hazards* include pesticides and other chemical residues; they have less dramatic and immediate effect than microorganisms but have long term effects on human health and have direct and indirect effects on the environment, flora and fauna. Other chemical hazards include toxic elements, such as lead, cadmium, arsenic and zinc, and naturally occurring compounds, such as oxalates in green leafy vegetables and alkaloids (e.g. solanine) in potatoes.
- Chemical hazards can be introduced during production through fertilizers, antibiotics, phytosanitary products and growth regulators.
- Chemical hazards can also be introduced during postharvest operations through waxes, phytosanitary products and detergents.
- *Physical hazards* include glass, wood, stones, hair, plastic, and metals.
- Hazards and their associated risks are increasing because vegetables are primarily consumed in the fresh form and/or with minimal cooking, there is increasing emergence of new foodborne pathogens, and global trade of vegetables is increasing.
- Food safety hazards should be prevented throughout the value chain.

Costs associated with food safety outbreaks

To the consumer

- Costs of medical care
- Missed work and lost wages
- Expenses for care
- Chronic disease
- Waste of time

To the exporter

- Loss of market access and credibility
- Losses of foreign revenue
- Loss of competitiveness
- Loss of reputation

To the vegetable sector

- Complaints and produce rejection
- Closure of business
- Penalties

- Disputes
- Loss of prestige
- Cost of corrective actions (investments)

To the government

- Health care costs
- Loss of foreign revenue
- Lack of consumer confidence

Role of growers and handlers

- Personnel associated with growing and harvesting should apply Good Agricultural Practices (GAPs) and protect harvested produce from contamination.
- Personnel associated with growing and harvesting should apply good hygienic practices (GHP) in the field and in all handling operations, and protect harvested produce from contamination.
- Personnel should ensure proper sanitation of harvesting equipment and tools, packhouse facility, equipment and surroundings, containers, and transport systems. *Sanitation is about attention to details.*
- Proper records must be kept in order to facilitate traceability.
- Keep records on seed quality; pesticide application; water quality (irrigation and wash in packhouse); soil analysis; pest control program; postharvest treatment; cleaning and maintenance program (establishment, machinery, tools, etc.); and workers' training.

Good Agricultural Practice (GAP)

- Sanitary procedures in production, harvesting, packing and shipping to prevent or minimize contamination with human pathogens.

Farm resources

- Factors to consider include irrigation water, general soil quality; land use, and proximity of the farm to animals, manure or faecal matter and hazardous water storage areas.
- Enteric pathogens are common contaminants of vegetables, where contaminated irrigation water or sewage sludge as fertilizer are used.
- Most vegetables contain nutrients that can support growth of pathogenic microbes. Once contaminated, removal or destruction of

pathogens is very difficult. Prevention at all steps of the value chain is strongly advised over treatments to eliminate contamination.

- Human resource in the farm plays a role in the spread of pathogenic microorganisms. Workers' training and GAP are important to prevent the problem.
- A properly implemented GAP program should include consideration of: the history of land use; worker hygiene and sanitary facilities; control of wildlife and pests; water quality and application of water; and management of soil fertility.
- Documentation of manure use, water test results and food safety awareness training of workers are also critical elements.

Farm manure

- Animal manure (biofertilizer) or other waste products are often used to promote plant growth and soil fertility, but could lead to contamination of fresh produce with foodborne pathogens.
- Manure should be treated (i.e. composted, dried, heated or decontaminated in some other way) prior to application in the field.
- Manure must not be spread between crops if direct contamination is likely.

Agricultural water

- Water used in production can introduce pathogens into the value chain.
- Water sources must be frequently tested for microbial contamination.
- In situations where water quality cannot be controlled (e.g. water from river or lake), producers should use other good practices to minimize risk of contamination, such as minimizing contact of water with the edible portion of the plant.

Animal faecal contamination

- Wild and domestic animals and birds often roam rural landscapes and can pose a contamination risk.
- Steps must be taken to exclude the presence of these animals in production areas during the growing and harvesting season.
- If herds of animals are known to frequent or roam certain agricultural plots, alternative plots should be selected or a diversion/containment strategy implemented.

Workers' training

- All workers must be trained in hygiene practices with constant reinforcement of the importance of personal hygiene and sanitation.
- Workers must also be adequately equipped with hand washing and sanitation facilities in accordance with specific requirements.

Good hygienic practice (GHP)

- Practices to ensure safety throughout the food chain, with emphasis on prevention and control of microbiological hazards.
- A horizontal component of GAP and Good Manufacturing Practice.
- Basic rules for hygienic handling, storage, processing, distribution and final preparation of food along the food production chain are set out in the Codex General Principles of Food Hygiene.
- These include requirements for the design of facilities, control of operations (including temperature, raw materials, water supply, documentation and recall procedure), maintenance and sanitation, personal hygiene and training of personnel.
- GHP forms an integral of all food safety management systems including Hazard Analysis Critical Control Point (HACCP).

Good manufacturing practice (GMP)

- Practices to prevent and control hazards associated to vegetable postharvest chain, ensuring a safe and wholesome product, while minimizing the negative impact of those practices on the environment and on workers' health.
- Areas of concern include personnel hygiene, location of facilities (packhouse, storage), sanitary operations, sanitary facilities and controls, equipment and utensils, and processes and controls.

Hazard Analysis Critical Control Point (HACCP)

- A system approach that identifies potential sources of contamination in food production systems, establishes methods for detecting the occurrence of contamination, and clearly prescribes corrective actions to prevent consumption of contaminated foods.
- HACCP basic principles (e.g. Figure 15):

  (1) assessment of hazards

  (2) determine critical control point (CCP) to control the hazards

(3) establishment of CCP limits

(4) establishment of CCP monitoring procedures

(5) corrective action when deviations from CCP limits occur

(6) verification system

(7) record keeping

Figure 15 Sample HACCP model for fresh produce washing in the packinghouse.

HACCP model for fresh produce

Flow process	*Hazard category*	*CCP*	*Critical limit*	*Monitoring*	*Frequency*	*Corrective action*	*Record keeping*	*Verification*
Washing	Microbial	Water Cl_2 and pH	Cl_2 100 ppm, pH 6-7	Test kit pH meter	Every hour	Adjust water chemistry, repair system, hold produce, rewash	Cl_2 and pH record	Random sampling, microbial count

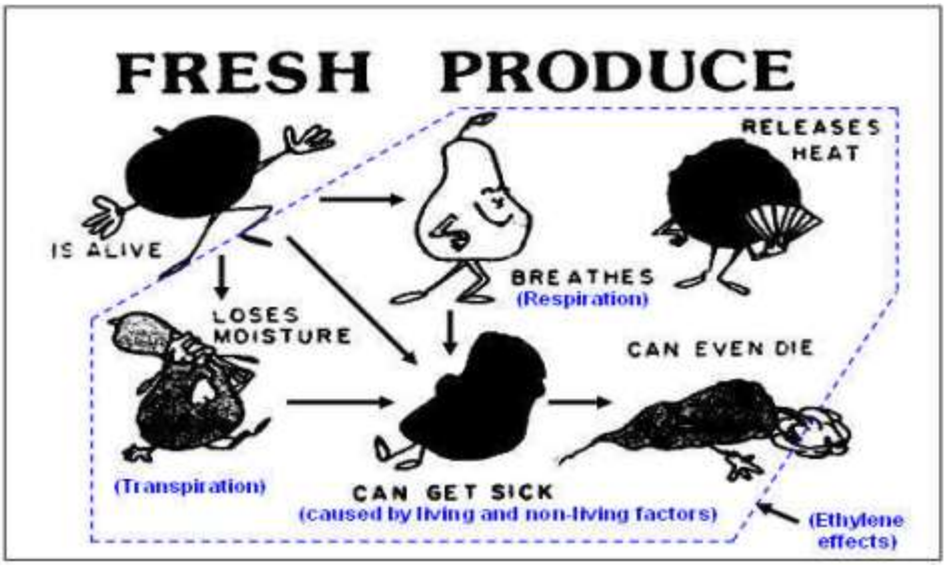
- HACCP prerequisite programmes include GAP, GHP and GMP.
- In practical terms, GAP, GMP and GHP are incorporated into the code of practices and protocols for certification under a generic concept of *Good Agricultural Practice.*

V. Factors Affecting Vegetable Quality

Physiological factors

- Harvested vegetables are composed of living cells and tissues.
- Since they are cut off from the growing medium, harvested produce has to live on stored reserves (carbohydrate and water). Depletion of carbohydrates through respiration and loss of water through transpiration lead to quality loss (Figure 16).

Figure 16 Basic characteristics of fresh vegetables.



- Respiratory and water losses could stress the produce. Any stress stimulates production of ethylene, the ripening or senescence hormone, which further accelerates quality deterioration.
- Being a source of food (sugars) for microorganisms, fresh produce is prone to invasion by spoilage and pathogenic microorganisms.
- If the produce is for fresh marketing, the goal after harvest is to maintain the living nature of produce for as long as possible.
- If the produce is to be processed after harvest, the goal after harvest is to avoid loss of desired processing attributes.
- A basic understanding of physiological processes is important for effective maintenance of product quality.

Respiration

- breakdown of carbohydrates to carbon dioxide, water and heat in the presence of oxygen:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Heat (2830 kJ)}$$

  Implication: Reducing O_2 or increasing CO_2 level (e.g. modified atmosphere packaging, surface coating and controlled atmosphere storage) reduces respiration, preserves quality, and extends shelf life.

- However, too low O_2 and/or too high CO_2 levels lead to anaerobic respiration (fermentation) causing physiological disorders and alcoholic flavor (off-flavor).
- Respiration leads to losses of dry weight, food value, flavor, texture and overall quality.
- Respiration may be climacteric or non-climacteric.
- Climacteric produce (e.g. tomato) exhibits a final increase in respiration during ripening. Retarding this final respiratory surge delays ripening and extends shelf life. Climacteric fruit can ripen normally after harvest when harvested mature green.
- Most vegetables are non-climacteric, i.e. they do not exhibit final respiratory increase before they senesce or completely deteriorate in quality. For non-climacteric fruit like chili, they are usually harvested ripe since they do not have the capacity to ripen normally after harvest.
- The higher the respiration rate, the faster the rate of quality deterioration and the shorter the shelf life. Table 1 shows the relative respiration rates of vegetables.

Table 1 Relative respiration rates of vegetables.

Relative rate	**Respiration at 5°C ($mg\ CO_2/\ kg.h$)**	**Climacteric**	**Non-climacteric**
Very low	<5		Dried fruit and vegetables
Low	5-10		Celery, garlic, onion, potato
Moderate	10-20	Tomato	Cabbage, celery, cucumber, pepper
High	20-40		Carrot, cauliflower, leeks, lettuce, lima bean, radish

Very high	40-60		Bean sprouts, broccoli, Brussel sprouts, green onions, okra, snap bean, watercress
Extremely high	>60		Asparagus, mushroom, peas, parsley, spinach, sweet corn

Transpiration (water loss)

- Evaporation of water (i.e. water changes from liquid to vapor in the presence of heat) from the produce to the external environment.
- Exit of water vapor from the produce occurs when the water vapor pressure (i.e. amount of water vapor in air, usually indicated by percent relative humidity - RH) in the external environment is lower than that inside the produce (usually 98-100% RH).

  Implication: To reduce water loss, increase the RH and lower the temperature in the atmosphere surrounding the produce or provide barrier to water loss (e.g. surface coating).
- Most vegetables contain more than 80% water and tend to lose water after harvest.
- Product characteristics affect water loss. For example, tomato has more waxy skin (thick cuticle) hence lower rate of water loss than peppers. Leafy vegetables have thinner cuticle, more stomates and higher surface area, hence much higher rate of water loss than fruit or root vegetables.
- Water loss results to losses of saleable weight, visual quality due to wilting or shrivelling, firmness, crispiness, succulence, overall freshness, and water-soluble nutrients such as vitamin C.
- Water loss is the main cause of weight loss. Weight loss of >5% can render vegetables unmarketable due to shrivelling or wilting (Table 2).

Table 2 Maximum allowable water loss for produce to become unmarketable.

Commodity	Maximum allowable water loss (%)
Cabbage	7
Lettuce	3
Tomato	7
Peppers	7
Cucumber	5
Carrot	8
Potato	7

Ethylene production

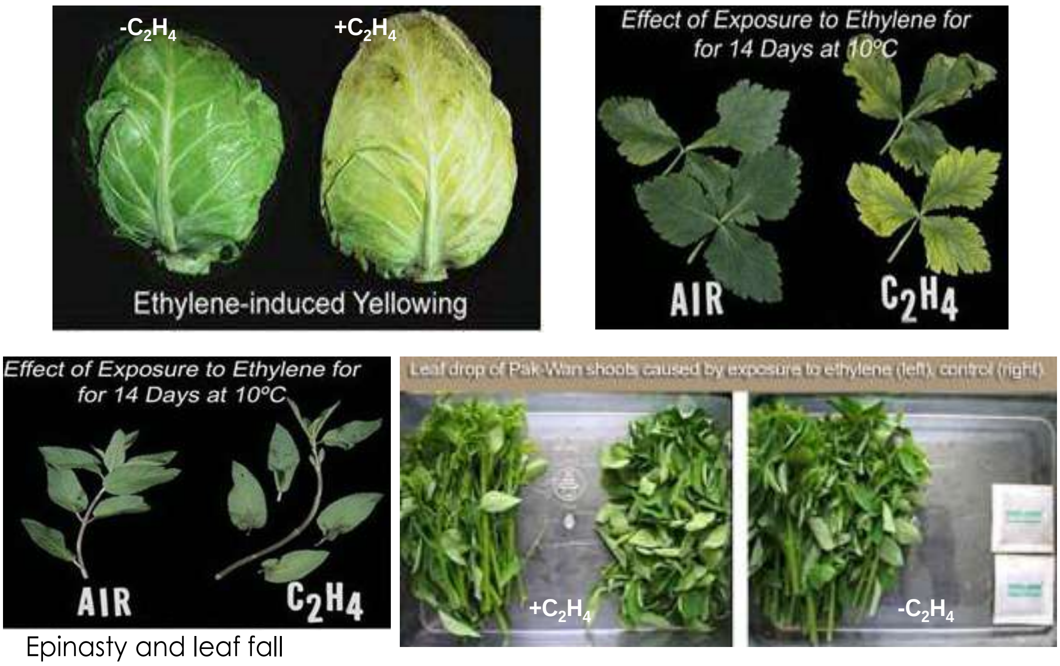
- Ethylene (C_2H_4), a gaseous plant hormone, initiates and speeds ripening and senescence; also called ripening or senescence hormone.
- All plant tissues produce ethylene at varying rates. Vegetables have relatively low ethylene production (Table 3) but are sensitive to ethylene, thus do not mix vegetables with high ethylene producers such as banana, apple, and other fruit.

Table 3 Relative ethylene production rates of vegetables.

Relative rate	Ethylene production at 20°C (ml C_2H_4/kg.h)	Climacteric	Non-climacteric
Very low	<0.1		Asparagus, cauliflower, leafy and root vegetables, potato
Low	0.1-1.0		Cucumber, eggplant, okra, chilli
Moderate	1-10	Tomato	
High	10-100		
Very high	>100		

- Harmful effects: ripening and softening of fruits, senescence and loss of green color in leafy, floral and immature vegetables (Figure 17).

Figure 17 Some harmful effects of ethylene on vegetables.



Epinasty and leaf fall

- Harmful effects of ethylene can be overcome by cold storage, controlled or modified atmosphere storage, ventilation of ripening rooms, segregation of ethylene producing produce from ethylene sensitive ones, use of ethylene absorbers in storage rooms and produce packs (e.g. potassium permanganate or $KMnO_4$) or use of ethylene inhibitor (e.g. 1-methylcyclopropene or 1-MCP).

Mechanical factors

- Mechanical damage or physical injury increases respiration, water loss, ethylene production and susceptibility to microbial infection.
- Mechanical damage may be seen as cut, bruise or deformation and often results in skin discoloration. It also affects nutritional and sensory quality of the produce.
- Mechanical damage may be due to impact, compression, abrasion or vibration.
- *Impact damage* occurs due to collision between produce items or between produce and hard surface; rapid acceleration or deceleration, e.g. when produce is dropped; or exertion of forces. It results in bruising with or without skin injury.
- *Compression damage* occurs when produce is subjected to heavy weight, with or without physical movement, as occurs when containers are of inappropriate depth, over-packed, packed in containers of poor structural integrity, improperly packed or stacked too high. It generally results in distortion, cracks and splits; usually caused by package failure and by stacking or sitting on top of produce.
- *Abrasion damage* occurs when surfaces of produce slide across another surface causing friction. It can result in removal of the cuticle and wax layers of produce.
- *Vibration damage* occurs when produce moves repeatedly for prolonged periods within a container during transport. Vibration can result in damage due to compression, impact and abrasion. The level of vibration of a moving vehicle is greatly influenced by the nature of the road and the suspension system of that vehicle. It is also caused by underpacking.

Microbiological factors

- Microorganisms cause spoilage of vegetables. Major postharvest diseases of vegetables are caused by bacteria and fungi.

- Diseases observed during the postharvest period may be of preharvest or postharvest origin.
- Disease symptoms that develop preharvest result in culling out of the affected commodity during harvesting, grading and packaging. Symptoms that develop postharvest are usually not detected prior to packing and shipping and result in significant losses to the producer.
- Disease inoculum or pathogen can contaminate produce before or after harvest. Microbial contamination can be transmitted through improper cultural practices, by workers and through contact with soil and unclean surfaces. Thus, quality management should consider both production and postharvest factors.

Entomological factors

- Insect pests can seriously disrupt trade among countries. Global trade requires strict control of phytosanitary measures to prevent the importation of insect pests.
- A large number of insects attack vegetables both pre- and post-harvest resulting in economic losses. About 750,000 insect species are currently known, of which 450 are considered serious pests.
- Insect pests of vegetables are usually most destructive at the larva stage. Among them, fruit fly is the most important pest in export trade. Other insect pests include bean pod borer and moths (e.g. diamond back moth of cabbages).
- Postharvest management of insect pests should involve the use of safe or non-chemical treatments such as heat treatment (hot water dip, vapour heat .treatment), cold sterilization, high carbon dioxide exposure or irradiation. Chemical control using insecticides should be avoided and if not, should be used at levels non-toxic to non-target organisms particularly humans.

Environmental factors

- Temperature, humidity, atmosphere or even wind movement affect product quality through their effects on respiration, water loss and ethylene metabolism as well as disease and insect pest attack.
- High temperature and low humidity increase the rates of physiological processes in most vegetables. Cold storage and high humidity storage are therefore employed to slow these processes and prolong shelf life.

- However, too low temperature results in physiological disorders such as freezing and chilling injury (surface discoloration; pitting). Similarly too low oxygen and/or too high carbon dioxide in storage or package cause physiological disorders due to fermentation.
- Recommended storage temperature usually ranges from 8-13°C for tropical produce and 0-5°C for subtropical produce while for oxygen and carbon dioxide levels, 3-5% and 5-10%, respectively.

Production factors

<u>Crop variety</u>

- The quality and potential shelf life of vegetables are partly under genetic control and can be manipulated by breeding.
- Breeding for long shelf life, desired shipping quality, high nutritional value and good processing attributes is needed in developing countries where refrigerated facilities are lacking, postharvest loss is serious, and malnutrition is prevalent.
- WorldVeg has introduced advanced lines of tomato and chili with desired postharvest traits for national testing worldwide. From these national trials, promising lines were identified for mainstreaming in variety development. Examples are:

  Bangladesh: Long shelf tomato lines include CLN3946, CLN3948, CLN3949 and CLN3954 with yield of 2-12 tons and shelf life of 8-10 days more than that of local check (BARI Tomato-14). Processing tomato lines include CLN3670B, CLN3552C, CLN3552B and CLN3125L-5X65 with comparable traits as the check (GPT0017 with AVRDC parent)

  Cambodia: Long shelf life tomato lines include CLN3940, CLN3947, CLN3949 and CLN3961 with yield of 4-14 t/ha more than that of local check (Mongal). Processing tomato lines with high soluble solids content include CLN3682C, CLN3669A, UC204A(=BL444) and CLN3125L-5X65.

  Nepal: Long shelf life tomato lines include CLN3940, CLN3947, CLN3949 and CLN3953 with yield of 22-80 t/ha and shelf life of 2-8 days more than that of local check (Pusa Ruby). Processing tomato lines include CLN3669A, CLN3552B and CLN3125L-5X65 with more than twice higher soluble solids content than local check.

- Earlier, WorldVeg identified promising tomato and chili lines with good postharvest traits in Cambodia, Laos and Vietnam (Table 4). Most of these lines are now commercially grown in these countries.

Table 4 Promising AVRDC tomato and chilli lines in Cambodia, Laos and Vietnam.

Crop	Cambodia	Lao PDR	Vietnam
Tomato	CLN1462A, TLCV15	CLN1462A, TLCV15	CLN2123A, CLN2498E
Chili	CCA321, 9955-15	CCA321, CCA323, PBC 142	CCA321, 9955-15

Climatic factors

- Temperature – High growing temperatures reduce red color (lycopene) and induce blotchy ripening (Figure 11) in tomato and increase puffiness (reduced solidity) in cabbage. Proper timing of planting, protected cultivation or use of high temperature-resistant varieties can minimize the problem. Optimum growing temperatures for tropical vegetables (e.g. tomato, chili, eggplant, leaf mustard) range from 20-32°C while for cool season crops (e.g. cauliflower), 15.5°C on average.
- Light – Shading in mustards before harvest results in rapid yellowing and wilting and lowers sugar, organic acids and chlorophyll contents. Too much light intensity may cause sunscald and increases plant temperature, resulting in high temperature-related quality defects.
- Rainfall – Too much rain towards harvest can result in the leaves becoming more brittle, making them more susceptible to mechanical injury and decay during handling and transport. Lettuce harvested during a period of rain has been found to have poor shipping quality thereby increasing product losses. Furthermore, outbreaks of foodborne illnesses have been traced to contamination of produce due to adhering soil particles during rainy period. Soil particles carry pathogenic microorganisms and the harvestable part of the plant (e.g. fruit or leaves) can be protected by mulching and trellising (e.g. tomato). Sanitary washing after harvest can also minimize the problem.

Cultural factors

- Appropriate growing practices and techniques generally result in the production of high quality and safe fresh produce.
- Seed material – Commercial growers must ensure procurement of seeds through certified suppliers to ensure optimum yields and resistance to pests and disease.

- Mineral nutrition – Excess or deficiency in soil nutrients affects produce quality and shelf life. Excess nitrogen application results in poor keeping quality and increased susceptibility to physiological disorders. In Brassicas, susceptibility to bacterial soft rot increased when nitrogen was applied as foliar spray. Low potassium level induces uneven coloration in tomato. Calcium deficiency induces blossom end rot of fruit vegetables (e.g. tomato-Figure 11). Boron deficiency induces hollow stem in brassicas and fruit deformation in fruit vegetables. Due to concerns of excessive fertilizer use (e.g. soil acidity, nitrate contamination of ground water and chemical residues), organic fertilizers are increasingly used. Farm manure as organic fertilizer should be used with caution as it could pose a food safety hazard.
- Irrigation – Adequate supply of water to the growing plant generally improves quality and storability of fresh produce. Drip irrigation has been found to improve yield and quality of chili, aside from increasing water use efficiency, as compared furrow irrigation. Using irrigation water from a farm pond used by livestock or from contaminated river is not encouraged due to food safety risk; otherwise, direct contact with harvestable part must be avoided.

VI. Harvesting and Field Handling

Harvest maturity

- Quality cannot be improved after harvest. It is therefore important to harvest vegetables at optimum maturity.
- Tomato:
  - Harvest at the mature-green, breaker, pink or firm-ripe stage (Figure 11), depending on the purpose for which they are grown, time of shipping, or distance from production to market or point of consumption.
  - For distant markets or if longer storage period is desired, tomatoes are harvested mature-green or less ripe (e.g. breaker stage). Being a climacteric fruit, mature-green tomatoes can ripen normally and can develop optimum quality. Immature fruit will not develop full color and flavor and deteriorate faster.
  - Mature-green fruit is determined by cutting fruit sample and the seeds will slide without being cut. Gel formation is advanced in at least one locule and jellylike material is forming in other locules. Fruit having similar size and appearance are considered mature. Experienced pickers gauge mature-green fruit based on full size and glossy appearance.
  - Mature-green fruit can better withstand rough handling during shipping thus losses are minimized. However, mature-green fruit may not be of desired ripeness when they reach the point of sale or utilization. So, additional holding for normal ripening to occur or artificial ripening treatment become necessary. Pink or red-ripe fruit are usually desired by consumers and processors.
  - For nearby markets, tomatoes can be harvested at the breaker, pink or firm-ripe stage which can be easily and non-destructively seen.
- Eggplant: Harvest fruit at immature but of full size (high yield) or size desired by markets before seeds begin to enlarge and harden. Firmness and glossiness are also maturity indicators and can be combined with the number of days elapsed from flowering (10-40 days depending on variety). Overmature fruit are pithy, bitter, hard and may show yellowing.

- Cauliflower: Harvest at the tight curd stage and when full size. Overmaturity is marked by elongation of individual curd (Figure 11).
- Leafy mustard, Chinese kale and other leafy vegetables: Harvest when full size but young/immature, combined with the number of days elapsed from planting. Overmature leaves are tough and bitter. Older leaves also turn yellow more quickly than younger leaves.
- Cabbage: Harvest heads when firm. Firmness (compactness or solidity) is determined by hand pressure. Compact head is only slightly compressed with moderate hand pressure. Some sample heads may be cut longitudinally and if the internal stem is too long, the head is already overmature. Delaying harvest even a few days beyond maturity can result in split or cracked heads and increased incidence of rots. Immature heads are puffy (have hollow spaces inside) since the inner leaves are not fully developed, making them more susceptible to damage. Yield is also lower and shelf life is shorter than mature ones.
- Chili: Harvest fruit when ripe, at least 80% reddening; can also be harvested green for specific purpose but green fruit will not ripen normally as chili is non-climacteric.
- Bitter gourd, cucumber, eggplant and yardlong bean: Harvest at desired size but young/immature and tender. Overmaturity is indicated by yellowing in bitter gourd and prominent seed bulging in beans.

Time of harvest

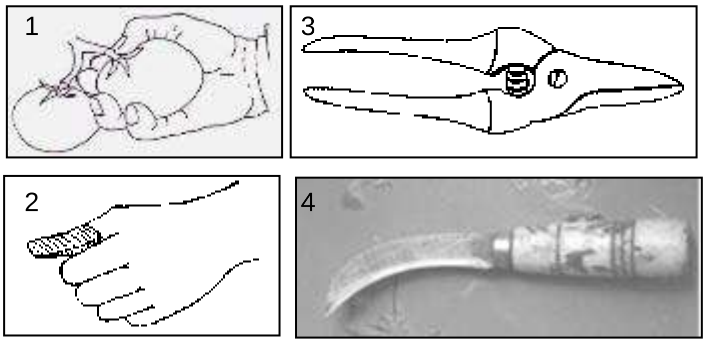
- Harvesting at cooler times of the day minimizes product heat load and increases work efficiency of pickers. Care should be observed because the plants and leaves are brittle (high water content) and prone to damage. It is also important to protect from damage the developing plant or fruit for subsequent harvest.
- In some cases, harvesting when the sun is up is practiced since the produce is less brittle and more resistant to damage during subsequent handling. In this case, the harvested produce should be moved to a shaded area to reduce heat load and water loss. The produce should also be allowed to dissipate heat before packing. High product temperature accelerates quality deterioration due to increased water loss and respiration.
- Harvesting in the later part of the day is advantageous in certain cases. The produce is less turgid, hence less prone to physical damage. Sugar content in leafy vegetables is also high as a result of photosynthesis during the day which could slow down leaf yellowing after harvest.

- Harvesting during or just after rain is not recommended as wet condition (rain water on the leaves or fruit) favors microbial growth and enhance tissue breakdown. If harvesting cannot be avoided during rainy days, the produce must be washed and dried properly before packaging.

Harvesting method

- Carefully harvest produce to minimize physical injury and preserve quality.
- Use harvesting aids as they can reduce labor cost, improve harvest efficiency, maintain produce quality, and speed the harvest and field handling. Protective clothing should also be worn for pickers' protection from plant hairs or trichomes (tomato, eggplant, cucumber, okra) or sap (chili) that may cause skin burning or allergy (Figure 18). Fingernails of pickers should be trimmed before harvesting to avoid nail-wounds on the produce.

Figure 18 Some harvesting aids and protective clothing.



Handpicking (1) with nipper (2); clipper or shear (3); knife (4)

Smooth-surfaced harvest containers; pickers in protective clothing

- Tomato, eggplant, cucumber and other fruit-vegetables: cut the calyx-stem free from the plant. Avoid pulling fruit to prevent removal of stem end and damage of plant and fruit for subsequent harvest. Pulling fruit from the plant may remove the pedicel, exposing the stem-end which, in tomato, is the main avenue for water loss and respiratory gases.

- Cauliflower: Harvesting should be done with great care to prevent damage to the highly sensitive turgid curds. Cauliflower should never be handled at the curd portion of the head. Cauliflower should never be allowed to roll or scuff across a harvest -conveyor belt, table, or other work surface. Bruising is very common and leads to rapid browning and decay.
- Leafy mustard: Harvest single leaves or whole plants with a knife. Care must be observed to avoid leaf tearing and petiole breakage.
- Cabbage and Chinese kale should be cut with knife rather than snapped or twisted to avoid damage and irregular cut and stalk length. Broken stalks are more susceptible to microbial decay. The knife should be sharpened to reduce effort and lessen picker's fatigue. The stalk should be cut flat or smooth and as close to the head as possible. Extra leaves act as cushion during handling and may be desired in certain markets. Yellowed, damaged, or diseased wrapper leaves should be removed.
- Fields may be harvested several times for maximum yield and desired quality, so care is needed to prevent damage to the plants for subsequent harvest.
- Use harvesting containers with smooth surfaces (e.g. plastic or metal buckets or trays). They facilitate collection with minimal or no damage to the produce. Cotton bag or small bucket tied to the picker's waist can also be used. Total weight per container should preferably be less than 20 kg for one person to easily carry.

Field handling

- Proper implements and care in handling the produce from field to packhouse reduce damage and preserve quality.
- Harvested produce is usually placed in collection containers, preferably plastic crate as it can protect produce from damage better than bamboo basket (Figure 19). Fruit harvested at different stages of ripeness can be sorted during the harvesting and field handling operations by either placing them in separate containers.
- In the farm, harvested produce is often exposed to the sun and in direct contact with the soil which is a rich source of pathogenic and

spoilage microorganisms. To avoid these, use appropriate ground cover, field sorting table and makeshift shed.

- Harvested mustards or Chinese kale can be exposed to the sun for about 30 minutes to induce temporary wilting and reduce handling damage. Subsequent washing to remove dirt could cool and re-hydrate the produce. Similarly, cabbages are exposed to the sun or allowed to stay in the field for about one hour as practiced in Cambodia. This will dry out the cut butt end, the usual entry point of soft rot bacteria. Since washing is not advisable, cabbages should be allowed to dissipate heat under shade before packing.
- Sorting and packing (packhouse operations), and loading to vehicle for transport to market can be done in the field (Figure 19).

Figure 19 Some field handling operations for vegetables prior to hauling to the packhouse or transport to market.

.Field handling: hauling, sorting, packing, weighing, and loading for transport to market.

Plastic crates as better collection container than bamboo basket

VII. Packhouse Operations and Packaging

Nature and importance

- A packhouse is a physical structure where harvested produce is consolidated and prepared for transport and distribution to markets.
- Packing is the main activity from which the name 'packhouse' is derived. But there are activities before and after packing – together they are called packhouse operations.
- Packhouse operations include receiving and recording, cleaning, sorting/grading, pre-treatments, packing, cooling, storage and dispatch to market.
- A packhouse enables quality assurance activities that ensure product quality and quantity meet market requirements and losses are minimized during transport and distribution to markets. Developing countries incur serious postharvest losses of vegetables usually ranging from 20-40% of production.
- A packhouse can serve as a hub for coordination and governance of a farm-packhouse-market organization in which market demand dictates production and packhouse activities.
- The activities depend on the type of produce and market. Fruit-vegetables may require certain operations not applied to leafy ones. Nearby markets may need only sorting and packing while for distant markets, additional operations are needed. When immediate transport is available, storage in the packhouse may not be necessary.
    - Tomato, eggplant, chili, cucumber, bitter gourd and yardlong bean: receiving – sorting – cleaning/sanitizing – airdrying – grading – packing – storage – dispatch
    - Cauliflower: receiving – sorting – trimming – packing – storage – dispatch
    - Leaf mustard: receiving – sorting/grading – trimming/cleaning – airdrying – packing – storage – dispatch
    - Cabbages and Chinese kale: receiving – sorting – trimming – bacterial soft rot control – airdrying – sizing – packing – storage – dispatch

Receiving

- The farm source and weight of produce are recorded upon arrival for accounting purposes. Record keeping is important in traceability system.

- Samples of produce can be collected and analyzed for pesticide residues using test kits if available. This can be used for product labeling for market credence.
- While waiting for the different operations, the produce should be protected from the heat of the sun and from sources of physical damage (e.g. heavy weights) and contamination (e.g, ground soil, stray animals).
- The produce can be inspected for the extent of damage (insect, disease and physical injury) and foreign matter to facilitate subsequent sorting and cleaning.

Sorting and Grading

- Sorting and grading can add 40-60% more value to the produce.
- Sorting and grading can reduce postharvest losses by:
  - Preventing disease contamination of sound produce which otherwise occurs when sound and diseased produce is mixed.
  - Minimizing ethylene damage (e.g. premature senescence or ripening) which otherwise occurs when injured produce or ripe fruit (high ethylene producers) is mixed with undamaged produce or unripe fruit.

- Sorting and grading facilitates production, packhouse operations and marketing when the quality grades used are recognized in a value chain or entire industry.
- Quality grades (or grade standards) serve as a universal language of trade and driver of technology adoption. Markets can place orders based on quality grades which will then be used to guide operations in the packhouse and farms.
- Sorting is done to remove damaged or diseased produce or those not meeting quality requirements. It is usually the first packhouse operation.
- Grading is done when the sorted defect-free produce is classified into grades or classes of specific weights or sizes (sizing) and maturity stage. It can be done after sorting or just before packing.
- Sorters/graders must be skillful and provided with adequate lighting and work breaks. Sorting aids should be used such as sorting tables (Figure 20) and color pictures of quality grading and defects (e.g. Figure 11).

Figure 20 Some simple sorting tables for vegetables.

Cleaning

- Clean produce has higher market appeal and price than dirty ones.
- Cleaning reduces microbial contamination, physical damage and transport cost.
- Produce can be cleaned by:
  - trimming fruit stem of tomato or eggplant, roots of leaf mustard, leaves and butt end of cauliflower (Figure 12), cabbage or Chinese kale; in cabbage, retain 3-4 wrapper leaves for protection.
  - wiping tomato, eggplant or cucumber with clean soft cloth.
  - washing using clean water to remove adhering soil and other debris. After washing, the produce should be air-dried before packing.
- While cleaning, sorting can be done. Avoid contact of produce with the soil which is a rich source of spoilage and human pathogens (Figure 13).

Treatments before packing

- Sanitizers:
  - Washing in 100-200 ppm chlorine (mixing 4-8 tablespoons of commercial bleach, which has 5.25% sodium hypochlorite or NaOCl, per gallon of water) for 1-3 minutes can reduce microbial load and decay in tomatoes (Figure 21). The produce should be air-dried before packing.
  - Calcinated calcium from scallop powder applied as 0.01% solution (0.1 gram scallop powder per liter of water) as 3-5 minute dip enhanced food safety (Table 5). It was developed as a non-chlorine sanitize because of health concern on chlorine which reacts with organic matter in the produce to form trihalomethanes, a highly carcinogenic compound.

Figure 21 Reduction of Phomopsis rot in eggplant by chlorine wash.

Table 5 Aerobic plate count (APC)* in log CFU/g on tomato and eggplant.

Sanitizer	Tomato			Eggplant
	Bangladesh	Cambodia	Nepal	Bangladesh
Calcinated calcium, 0.01%	3.2	6.1	3.7	3.7
Chlorine, 150 ppm	3.2	6.3	3.3	3.2
Water (control)	5.4	6.7	8.3	5.2

APC of 5 log CFU/g is generally considered as the microbiological food safety limit.

- Soft rot control – Bacterial soft rot is the most serious problem in cabbages in the humid tropics (Figure 22). Applying 10% alum (10g alum/100 ml water), lime paste (mix lime powder and water at 1:1) or guava leaf extract (mix pure extract and water at 1:1) on the butt end of cabbage reduced trimming loss due to soft rot to 0–20% from 20–44% without treatment, resulting in net return of 0.09–0.16 USD/kg produce based on studies in Cambodia, Laos and Vietnam.

Figure 22 Controlling cabbage soft rot with alum, lime or guava leaf extract.

- Chitosan – Extracted from local shrimp waste in Cambodia, chitosan at 1% (10g/liter water) as 5-min dip delayed ripening and increased shelf life of tomato by 6 days more and reduced weight loss by 50% lower than that of untreated fruit, giving a net return of 0.20 USD/kg produce.

Packaging

- Packaging is the main packhouse operation. It must provide protection of produce from damage but existing practices remain wanting; in Figure 23, for example, most produce are damaged or bruised on arrival at market destinations. Poor packaging is a major cause of losses.

Figure 23 Some existing packaging practices in Bangladesh, Nepal and Cambodia.

400-kg basket of eggplant Bangladesh | *100-kg sacks of cauliflower Nepal* | *200-kg basket of leafy vegetable Cambodia*

- Several packaging materials are available (Figure 24). Package selection depends on the type of produce, distance and mode of transport, and market.

Figure 24 Vegetable containers: bamboo and plastic baskets; plastic crates; wooden crates with inner cardboard sides and collapsible type; carton and foam boxes.

- Rigid containers, such as wooden or plastic crates, are more advisable but for wooden crates and other containers with rough surfaces, liners such as used newsprint, should be used.
- Protective packaging measures (Figure 25):
  - 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 of produce.

Figure 25 Protective packaging: use of liners and cushion (newsprint), individual wraps, vents in carton box to minimize heat buildup, and proper strapping.

Modified Atmosphere Packaging (MAP)

- MAP is the sealing of produce in plastic bags (Figure 26) to establish an atmosphere of low oxygen and high carbon dioxide, and humid condition that slow metabolic processes and water loss.

Figure 26 MAP practices for vegetables.

- Commercial plastic bags are used: 25 micron-thick (with market label as 001 film) low-density polyethylene (LDPE), high-density PE (HDPE) or polypropylene (PP) films. Thicker films (002-004) are not advisable due to increased water condensation inside the bag that favors rotting. Place produce inside the bag, seal, and keep for 3-10 days (usual duration of transport or storage/ temporary holding period), then in the open.
- Benefits of MAP are high (Table 6).

Table 6 Technical and economic benefits of MAP for vegetables.

Vegetable	Weight loss, %	Shelf life, days	Net return, USD/kg (partial budget)
Tomato	1-8 (6-20)	15-19 (9)	0.13-0.36
Chili	0-1 (9-12)	6-9 (3-6)	0.40-0.65
Eggplant	0-4 (6-22)	4-14 (2-5)	0.20-0.80
Leaf mustard	1-5 (11-28)	3-4 (1)	0.10-0.35
Cauliflower	25 (31)	9 (7)	0.10
Bitter gourd	1 (6)	4 (2)	0.30
Cabbage	1-5 (19-22)	12-24 (8-14)	0.21-0.48
Chinese kale	1 (37)	3 (1)	0.32
Cucumber	0 (10)	4 (2)	0.25
Kangkong	2 (22)	3 (1)	0.09
Long bean	0 (12)	3 (1)	0.15
Mustard, aromatic	4 (14)	3 (1)	0.58

Values in parentheses are responses of produce with no MAP (control); storage was at ambient, crop varieties were the commercial ones, and samples were at commercial harvest maturity. Results were from AVRDC projects in Bangladesh, Cambodia, Nepal, Laos and Vietnam.

Dispatch to market

- During loading to the transport vehicle at the dispatch area of the packhouse, care should be observed in handling the packages of produce to avoid physical damage and package failure. Protection from sun or rain should be provided.
- To facilitate loading, some equipment can be used (Figure 27). Proper records of dispatched produce should be kept for financial accounting.

Figure 27 Some packhouse equipment used during dispatch to market.

Weighing scale

Hand jack

Conveyor in loading and unloading

VIII. Cooling and Storage

Nature and importance

- Cooling is the foundation of produce quality protection as it slows metabolic 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 exposure to the sun or evaporative cooling storage).
- Desired temperature and relative humidity (RH) for vegetable storage (Table 7) are usually achieved by mechanical refrigeration system which is expensive. Low-cost alternatives are described here.

Table 7 Recommended temperature and RH for vegetable storage and handling.

Commodity	T (°C)	RH (%)	Storage life	Commodity	T (°C)	RH (%)	Storage life
Amaranth	0-2	95-100	10-14 d	Jicama	13-18	65-70	1-2 mo
Asparagus	0-2	95-98	2-3 wk	Leek	0	95-100	3 mo
Bean, snap	4-7	95-98	7-10 d	Lettuce	0-1	95-100	2-3 wk
Bean, lima (in pod)	5-6	95	5 d	Melon, honeydew	7-10	90-95	2-3 wk
Beet, topped	0	98-100	4-6 mo	Okra	7-10	90-95	2-3 wk
Bittermelon	12-13	85-90	2 wk	Onion, green	0	95-100	4 wk
Broccoli	0	95-98	10-14 d	Onion, bulb	0	65-70	6-8 mo
Cabbage	0	98-100	3-6 wk	Parsley	0	95	2-3 wk
Carrot	0	95-100	4 wk	Peas	0-1	95	1-2 wk
Cauliflower	0	95-98	2-4 wk	Pepper, sweet	7-10	90-95	2 wk
Celery	0	95-98	2-4 wk	Potato	4	95	3-5 mo
Chayote	7	85-90	1-2 wk	Radish	0	95	3-4 wk
Chinese cabbage	0	95-100	2-3 mo	Squash	5-10	95	1-2 wk
Corn, sweet	0	95-98	4-8 d	Taro	7-10	85-90	3-5 mo
Cucumber	10-13	90-95	10-14 d	Tomato	10-13	85-90	7-10 d
Eggplant	12-15	90-95	7 d	Watermelon	10-15	90	2-3 wk
Garlic	0	60-70	6-7 mo	Winged bean	10	90	2-3 wk
Ginger	13	65-75	4-6 mo	Yam	16	70-80	3-6 mo

Source: FAO 2012

- General guidelines in vegetable storage:
  - Only good quality produce should be stored; sort and clean them.
  - Use containers that can be easily moved in and moved out of the storage chamber and that can be stacked without causing damage.
  - In prolonged storage, the produce should be checked periodically to cull out diseased or deteriorated produce and prevent disease spread.

- Before placing the produce in the storage chamber, the desired temperature and RH should have been established. If cold storage is used, it is advisable to precool the produce

Precooling

- A precooling method to rapidly remove product heat before cold storage to slow metabolic processes and reduce heat load in the cool chamber. There are two simple designs; knockdown hydrocooler and overhead hydrocooler (Figure 28).

Figure 28 Simple knockdown hydrocooler (leftmost) and overhead hydrocooler applying cold water with water pump on the produce (middle and rightmost).

- The knockdown hydrocooler uses iced water (5ºC) for 10-15 min dipping while the overhead hydrocooler applies the 5ºC water with water pump for 15-30 min to bring down product temperature to 10ºC. The produce is then drained of excess water before keeping in the storage chamber.

Ice cooling

- Crushed ice is commonly used in packages to cool produce in transit to market (Figure 29). Direct contact of ice can injure the produce.

Figure 29 Ice cooling methods in packages of produce for transport to markets.

Ice packing *Ice bottle cooling*

- The ice bottle technique is an innovative way to avoid direct contact of ice with the produce. The ice bottles (2 pieces per pack of 25 kg vegetable) are wrapped with newsprint and placed in the package. Temperatures are reduced to 20–25°C from 35–40°C in packs of produce sealed in the afternoon and transported the following morning.

Coolbot cold storage

- The Coolbot technology uses a device that overrides the air conditioner's temperature gauge to lower the temperature from 16°C (lowest in an air-conditioned room) to 4°C, thereby converting an insulated room and air conditioner into a cool room, substantially reducing the cost of a cool storage environment (Figure 30).
- Temperatures are maintained at 11–13°C for tropical vegetables and 5–7°C for subtropical produce; shelf life markedly increased (Table 8). Do not mix these two types of vegetables because if tropical produce is stored at 5–7°C, they will develop chilling injury while if subtropical produce is stored at 11–13°C, they will have shortened shelf life.

Figure 30 Coolbot cold storage with the Coolbot device connected to the air conditioner.

Table 8 Shelf life and weight loss of vegetables stored in the Coolbot.

Vegetable	Weight loss, %		Shelf life, days	
	Coolbot	Ambient	Coolbot	Ambient
Tomato	5	10–12	18–24	9–12
Eggplant	2	7	14	4
Leaf mustard	5	13	6	0.5

Results were from AVRDC projects in Bangladesh and Cambodia; Coolbot temperature was maintained at 12–13°C while ambient temperature varied from 22–35°C. Crop varieties were the commercial ones and samples were at commercial harvest maturity.

- The Coolbot maintains lower RH than the recommended one often below 50%, rapidly desiccating vegetables. Providing wet cloth or pan of water, misting with water or keeping produce in MAP can maintain high RH.

Evaporative cooling storage

- Cooling by evaporation of water provided in the vicinity of produce. The decrease in temperature is small, usually 1-8°C lower than ambient, but RH increases to more than 90%. It is effective in reducing weight loss.
- Simple evaporative cooler (EC) structures (also called zero-energy cool chamber as it does not use electricity) are shown in Figure 31. They reduced weight loss and improved shelf life of vegetables, resulting in high net returns (Table 9).

Figure 31 Brick-walled and box-type evaporative coolers (EC).

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

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

Table 9 Technical and economic benefits of storage of vegetables in evaporative coolers.

Vegetable	Weight loss, %	Shelf life, days	Net return, USD/kg (partial budget)
Tomato	1-7 (5-23)	12-15 (7-9)	0.24-0.34
Chili	4-6 (12)	6-8 (3-4)	0.28-0.33
Eggplant	1 (6)	4 (2)	0.20
Leaf mustard	3-15 (15-28)	3 (1)	0.14-0.26
Cauliflower	18 (44)	9 (7)	0.50
Bitter gourd	2 (6)	5 (2)	0.25
Cabbage	6-11 (19-22)	14-22 (8-16)	0.19-0.24
Chinese kale	4 (23)	4 (2)	0.22
Cucumber	3 (10)	4 (2)	0.18
Long bean	4 (12)	3 (1)	0.30
Mustard, aromatic	7 (14)	3 (1)	0.52

Values in parentheses are responses of produce stored at ambient. The vegetables were commercial varieties at usual harvest maturity. Results from Bangladesh, Cambodia, Nepal and Laos trials.

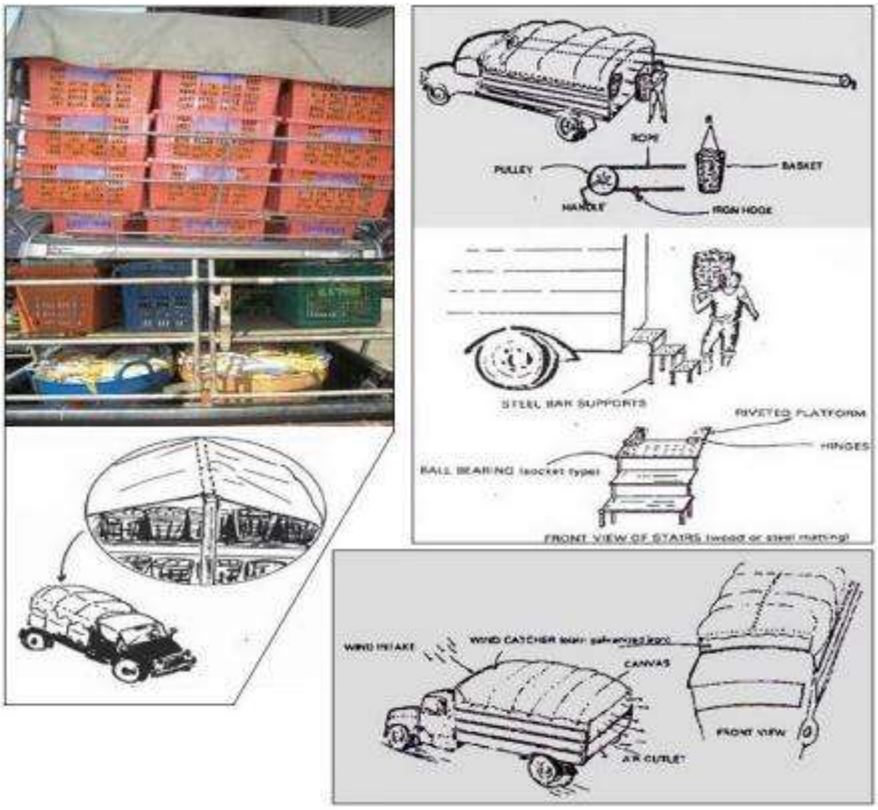
IX. Transport and Market Handling

Transport

- Transportation facilitates the rapid movement of fresh produce within the value chain. Fresh produce must be properly protected during transportation in order to minimise mechanical damage, temperature abuse, taint and contamination by food-borne pathogens. It is the responsibility of the transport provider to ensure that the transport vehicle is well maintained and is in a hygienic condition.
- 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 (similar to cold storage). In non-refrigerated transport, evaporative cooling and MA techniques can be applied (Figure 32).
- 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 (Figure 33).

Figure 32. Evaporative cooling (use of wet cloth) and MA liner in transport.

Figure 33. Transport measures to minimize losses: *A – canopied truck to protect from sun, rain or strong wind and separator between layer of containers; B – improvised conveyer and staircase to ease loading and unloading; C – ventilation system to minimize heat build-up in load.*



- Transport equipment includes:
  - Refrigerated and non-refrigerated vehicles – for highway transport
  - Containers for air, rail and highway transport, and for lift-on/lift-off sea transport
  - Break bulk refrigerated vessels – for handling palletised loads
  - Pallets – for air cargo and highway transport
  - Horse carts, donkeys
  - Wheelbarrows and carts – for transport over distances of 1-8km
- Transport of mixed loads can be of serious concern as with storage of mixed loads. Compatibility in terms of temperature, ethylene production and sensitivity should be considered. Wet and dry produce items must be transported in separate mixed loads to avoid transfer of contamination from wet to dry produce.
- Lack of hygiene in transport can adversely affect quality of vegetables. To prevent contamination by foodborne pathogens, transport systems should follow good sanitation practices, ensure proper temperature and RH management, and minimise potential damage to the produce.

Vehicles should be cleaned routinely to remove decaying remains of produce. Water used for washing must be safe and clean.

Market handling

- Operations at destination markets to provide consumers with best possible quality.
- Unload packages under cover, observing care to minimize physical damage.
- Re-clean, re-sort, re-pack and store produce following proper methods (Figure 34).
- Observe good sanitation – properly dispose rotten produce; clean and sanitize with 200 ppm chlorine packing/storage facilities, preparation areas and display bins.

Figure 34 Market handling activities.

X. Processing and Value Addition

Importance

- Processing is a value-added activity that stabilizes and diversifies food supplies and creates employment and income opportunities. It minimizes the high perishability problem of vegetables and extends availability of produce beyond the growing season.
- Processed products are more stable, have improved digestibility, and permit great diet diversity, giving consumers access to a wider choice of products and better range of vitamins and minerals.

Solar drying

- Vegetables are highly perishable due to their high water content, which contributes to high postharvest losses of up to 50%.
- Drying is the simplest method of processing to keep vegetables for longer periods of time and reduce losses after harvest.
- Sun-drying is the most economical and ecologically sound method, but is slow, weather-dependent, and exposes the product to food safety hazards such as stray animals, foreign matter and microbes. Aflatoxin-producing fungi can become a problem, especially when drying is slow and done without regard to good drying practices.
- Solar dryers accelerate drying and produce a hygienic product in an enclosed drying chamber. WorldVeg and its national partners jointly developed simple dryers for vegetables (Figure 35).

Figure 35 Simple solar dryers for vegetable drying.

Cabinet solar dryer *Solar dryer with solar heat collector & artificial heating chamber* *Greenhouse solar dryer*

- The simple solar dryers maintain temperatures of 15-35°C higher than open sun-drying conditions; too high temperatures (>60°C) can result in low quality product (discolored, loss of critical nutrients and antioxidants).
- Tomato and eggplant slices, whole chili fruit, cabbage shreds and cauliflower florets dry in solar dryers to <10% moisture in 1-3 days compared to 2-6 days under open sun-drying (Figure 36).

Figure 36 Process flow for producing solar dried tomato powder (top), chili fruit (middle) and cabbage shreds (bottom).

- 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.

Paste production

- Tomato paste is a concentrated product with minimum soluble solids of 24% (Codex standard 57-1981). In contrast, tomato puree and tomato sauce have lower soluble solids of at least 7% but less than 24%. The moisture content also differentiates the three tomato concentrates and is lower in paste than in puree and sauce. Paste and puree retain the tomato flavor while sauce contains characterizing ingredients in quantity that alter the tomato flavor.
- The desired soluble solids of paste can be determined through viscosity, i.e. the paste becomes sticky on the teaspoon and flows slowly on the paper, if refractometer is not available,
- Deep red, big-fruited varieties are more desired to facilitate removing unneeded parts and obtain the desired red color.
- 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 $<10^{1-3}$.
- Figure 37 shows the paste processing procedures. Red fruit are 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 which are then pasteurized.
- Table 10 shows the technical and economic benefits of paste processing optimized in three countries.

Table 10 Benefits of tomato paste processing optimized in three countries.

Country	Technical benefits	Economic benefits by profit analysis
Bangladesh	Adding acetic acid @ 6 ml kg^{-1} pulp was the most desirable; it had longest shelf life of 5 months at ambient (24-30 °C).	0.27 USD/400g bottle
Nepal	Non-spicy sauce preferred over spicy product	0.10 USD/ 250g bottle
Cambodia	Best quality paste from var T56 fruit while paste from CLN1462A and TLCV15 fruit had more stable storage quality Desired paste color obtained using deep red fruit	0.25 USD/ 400g bottle

Figure 37 Tomato paste processing procedures.

Select deep-red fruit; wash in clean water

Steam for 30 min to ease skin removal; remove skin; slice and scoop out seeds; and blend pulp with a blender

Prepare flavor ingredients (optional)

Squeeze out juice with meshed cloth; cook to concentrate with periodic stirring and checking soluble solids to 24% as endpoint (If refractometer is not available, desired soluble solids can be determined through viscosity of paste, i.e. sticky on teaspoon and flows slowly on the paper.); and add flavor ingredients

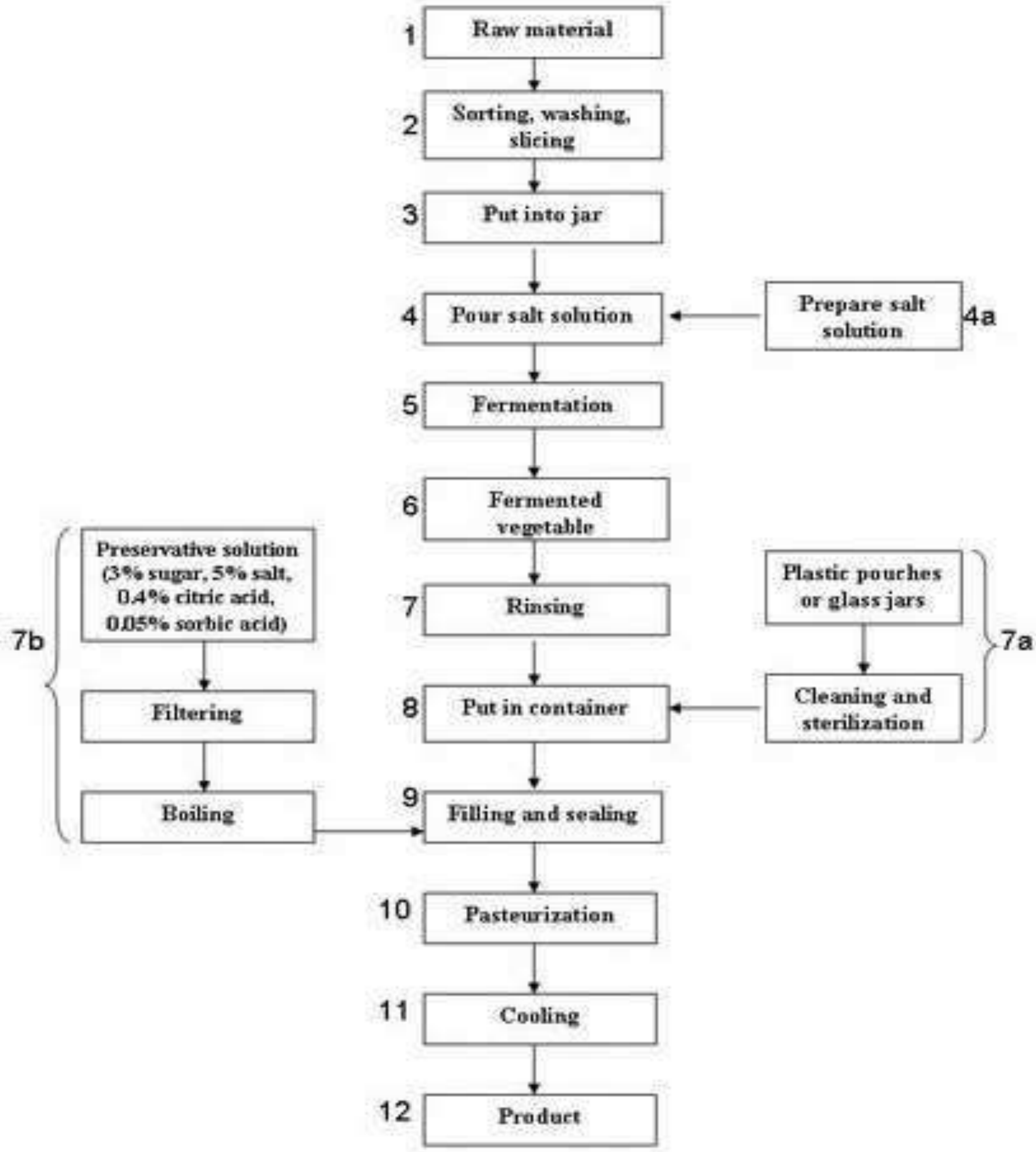
Dispense paste into sterilized bottles while still hot (about 65ºC)

Pasteurize in 80ºC water for 10 min; cool to ambient; put label/brand; and store in a dark place

Fermentation

- Fermented vegetable is produced through the action of lactic acid bacteria (LAB) which enhances the nutritional value by increasing vitamin levels and improving digestibility.
- Traditional fermentation could keep the product for only 1-3 days. Employing GMP and appropriate preservative, the product can be kept for at least one month.
- Figure 38 shows the fermentation procedures.

Figure 38 Fermentation procedures.



1 – Raw material (fresh vegetable); 2 – Remove damaged leaves, slice them into half (mustard) or quarters (cabbage), wash in tap water, and air-dry; 3 – tightly arrange the vegetable into the fermentation jar (Figure 39); 4 – prepare 8% salt solution (4a) and pour into the jar; 5 – cover jar with slatted material and put weight at 60% of total weight of vegetable and salt solution, and ferment for 2 days in summer or 4 days in winter; 6 – take out the vegetable from the jar; 7 – prepare rinsing container (7a) and prepare preservative solution (7b); Before the end of fermentation, prepare containers (plastic pouches) and preservative (mixture of 3% sugar, 5% salt, a.4% citric acid and a.a5% sorbic acid). At the end of fermentation, rinse vegetable in tap water and air-dry; 8 – dispense 300–500 gm vegetable per plastic pouch; 9 – Fill the plastic pouch with preservative solution at 30% net weight per bag (or 150 ml preservative solution per 500 gm vegetable per plastic pouch) and seal with a plastic sealer; 10 – Pasteurize by placing the pouches when water is heated to 60–65^{O}C; continue heating until temperature increases to 80^{O}C, maintain 80^{O}C for 10 min, and cool in slowly running tap water until 35^{O}C; 11 – Allow the pouches of vegetable to cool down to room temperature before storage; 12 – finished product

Figure 39 Fermentation in jars and glass bottle and plastic pouches of finished product.

- The optimized fermentation process has solved the limitations of the traditional method and resulted in significant monetary return (Table 11).

Table 11 Benefits of fermented vegetable production.

Commodity	Country	Technical benefits	Economic benefits by profit analysis
Leaf mustard	Cambodia	Fermented mustard kept for at least 1 week instead of less than 1d for fresh produce and 1-3d for traditional fermented product. Fermented product more hygienic than traditional product.	0.24 USD/500g bottle
	Laos	Improved method gave good color and taste and longer shelf life than traditional method	For technical recommendation
	Vietnam	Better sensory quality and shelf life than other salt levels and fermentation periods	0.09 USD/500g bottle
Cauliflower	Nepal	Fermented curds kept for at least 1 wk instead of 1-2d for fresh produce. Fermented product had safe level of microbial load of less than 10^5 log CFU/ml.	0.05 USD/250g bottle
Cabbage	Cambodia	Long shelf life but color and taste of product from the traditional method more preferred	For technical recommendation
	Vietnam	Better sensory quality and shelf life than other salt levels and fermentation periods	Cost & return analysis (CRA): 23.2% higher than that for fresh market

XI. Practical Exercises

1. Sorting/Grading, Cleaning and Sanitizing

- Purpose:
  - To acquire skills in quality grading and in developing quality grades.
  - To acquire skills in washing and sanitizing produce in the packhouse.
- Activities:
  - Each group will be given a lot of vegetables.
  - Perform sorting and weigh the selected and discarded produce.
  - For the selected produce, observe overall quality and formulate your own quality grades with specifications of quality per grade (e.g. Grade 1-best quality; Grade 2…)
  - Classify the produce based on the proposed grades and take the weight for each grade.
  - For another set of vegetables of 3 groups (1-sorted produce of the same ripeness; 2-sorted produce of different ripeness; and 3-unsorted produce), you will be asked whether you are willing to pay a higher price for the sorted produce and by how much higher compared to that of unsorted produce. The results will be averaged and discussed.
  - Demonstrate the sanitizing treatments using 0.01% calcinated calcium and 150 ppm chlorine, including preparation of the solutions.

2. Packaging Techniques

- Purpose:
  - To acquire skills in protective packaging using liners.
  - To acquire skills in the MAP of vegetables.
- Activities:
  - The use of liners (newspaper, banana leaves) in bamboo basket, wooden box or plastic crate will be demonstrated. The benefits of using liners will be discussed.
  - Using samples of priority vegetables, each group will be given different kinds of MAP bags; then, pack the samples in the bag.

- In separate samples of MAP and open produce set up 2 days before the training, the group will take the weight and color of the samples (and other distinct quality differences) and calculate percentages and averages. The results will then be discussed with the whole group.

3. Cooling and Storage

- Purpose:
  - To acquire skills in cooling produce by simple methods.
  - To acquire skills in storage techniques for vegetables.
- Activities:
  - Cooling with iced water will be demonstrated.
  - Observations on the storage of vegetables in evaporative cooler or Coolbot cold chamber set up 2 days before the training will be taken. Weight loss, color changes and decay data will be measured. The results will be discussed with the whole group.

4. Solar drying

- Purpose:
  - To acquire skills in vegetable drying using simple solar dryers.
- Activities:
  - For on-station trainings, bring the participants to the location of the solar dryers and discuss its construction and its mechanism and advantages in drying vegetables.
  - A pre-set up drying treatments (use of the solar dryers and sundrying) can be prepared for observation during the training.
  - For on-site trainings (mobile trainings), show in slides and discuss the solar dryers, their advantages and disadvantages, temperature and RH conditions, and effects on produce moisture content.

5. Tomato Paste Processing (for demonstration or actual performance)

- Purpose:
  - To acquire skills in producing tomato paster.

- Activities:
    - Prepare 8-10 kg red-ripe tomatoes and wash thoroughly in clean water in pail or basin.
    - Immerse fruits in boiling water for about 8-10 minutes and then allow to cool in water for 8-10 minutes.
    - Peel fruit with knife, slice and remove seeds using a teaspoon.
    - Homogenize pulp with a mixer, blender or mortar and pestle.
    - Pass the crushed pulp through a sieve to extract the juice.
    - Place the pan with pulp and juice on a stove with low heat to concentrate to 12% soluble solids.
    - Add and dissolve 2% salt and 1% pectin.
    - Resume cooking with periodic stirring using a wooden spoon until 24% soluble solids which can be checked with a refractometer or based on viscosity on a teaspoon (if paste does not flow readily, the product is done).
    - On a separate heating vessel, heat glass bottles in boiling water for 2a minutes and while still hot, fill each bottle to the brim with the hot paste, and then cover.
    - Place the filled bottles in boiling water for a period of time.
    - Allow to cool for 2 hours and store in cool condition.

6. Mustard Fermentation

- Purpose:
    - To acquire skills in producing fermented vegetables.
- Activities:
  - Since fermentation takes more than 2 days to complete, some parts of the process can be performed during the training. The whole process can be demonstrated through slides presenting the step-by-step procedures with pictures at each stage.
  - Alternatively, the leaf mustard can be fermented two days in advance of the training. During the training, the participants can perform the procedure until the produce is placed in the fermentation jars. After which, the participants can used the prepared fermented produce for subsequent operations.

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