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Horticultural Chain Management for Countries of Asia and the Pacific Region

A Training Package

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Horticultural chain management for countries of Asia and the Pacific region: a training package

Edited by

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Foreword

In 2005, in response to needs identified through consultative workshops in each of the developing regions, the Food and Agriculture Organization of the United Nations (FAO) embarked upon the design and development of training of trainer programmes to strengthen capacities in horticultural chain management. With funding from the Commonwealth Secretariat, a formal agreement was established with the University of Pretoria, South Africa, to develop a training package focused on practical approaches to assuring the safety and quality of horticultural produce and on the efficient organization of horticultural chains to improve the competitiveness of small and medium enterprises (SMEs) in East and Southern Africa.

In December 2008, a formal agreement was established with King Mongkut's University of Technology, Thonburi (KMUTT), Thailand, to tailor the original training package (consisting of a theoretical manual and a practical manual) to the context of Asia and the Pacific region and to test the adapted training materials by means of a subregional training programme for the least developed countries of the region. The work undertaken by KMUTT and various associates was funded through the Norway–FAO Programme Cooperation Agreement.

This training package is structured to provide trainers in Asia and the Pacific region with sufficient technical background and reference materials to allow them to customize training in accordance with the needs of the target groups to be trained. It includes a number of practical exercises that are designed to reinforce and enhance an understanding of theoretical issues presented in the theoretical modules.

It is hoped that the training package will stimulate improvements in horticultural chains across Asia and the Pacific region, leading to safer produce of higher quality, reduced losses and to better economic returns for SMEs and small scale producers.

FAO welcomes feedback from the users of this training package. Comments as well as contributions to the contents will help to improve future editions of this package and should be sent to Rosa.Rolle@fao.org.

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SECTION I

Planning and delivery of the training programme

Section I

Module 1 – Background and preparation for the training programme

Learning outcomes

The learner should understand how to:

- use the theoretical and practical manuals effectively for training; and
- plan and prepare a training programme.

Introduction

This module and the following two modules of Section 1 adopted, with some modification, the recommendations outlined in the *Theoretical manual for the training on horticultural chain management for East and Southern Africa*. Module 1 relates to the planning and preparation stage, Module 2, implementation of the training, and Module 3, post-training activities.

Background to the training package

The training package guides the trainer in preparing the needed resources appropriate to the context in which the training will be delivered. In order to derive maximum benefit from the training package, the trainer must study the theoretical and practical manuals, selecting the practical examples that are best suited to the training context (country, crops cultivated, target audience and so on). In preparing the training materials, the trainer must take into account the literacy level, language and knowledge base of the target audience.

Working through the theoretical manual

The theoretical manual takes the trainer through a step-by-step approach of progressive learning. It also provides the trainer with a platform of information that can be used to design and implement courses appropriate for his/her country context. Each section of the manual is presented in a modular format and is linked to a practical exercise. On completion of each module, participants are required to share information assimilated during the discussion session. Participants must also apply the knowledge acquired through the practical exercise.

Throughout the theoretical manual, references are provided as additional sources of information. It is essential that the trainer consult new information to ensure that he/she stays up-to-date with the latest trends and continuously improves and adapts the training materials. Many of the Worldwide Web resources cited are themselves continuously updated and represent an excellent source of basic information that can be used for tailoring courses to the needs of a target audience. At the time of publishing the training package, all Web sites cited in the practical and theoretical manuals were accessible.

Additional background material is provided in the Appendices. Other relevant information can be added or the information can be updated to ensure that it remains current.

Working through the practical manual

The practical manual complements the theoretical manual and provides simple practical tasks that reinforce and enhance comprehension of the theoretical components. It includes demonstrations, hands-on activities, tasks (e.g. carry out a survey or conduct interviews), problem-solving challenges and field visits with a focus on observation and recording. It can also be used to develop context-appropriate hands-on training packages for small-scale farmer-learner programmes.

Preparing for the training programme

A well-planned training programme is the basis of effective information transfer. It should integrate a number of dimensions including academic excellence, hands-on experience, discussion sessions, excursions, formal lectures and social interactions. These dimensions must be presented in a balanced format to ensure maximum absorption of information and knowledge sharing. Physical facilities such as the training venue should create an environment conducive to learning and delivery of the programme. The programme must also conform to the needs of the participants and must incorporate considerations of the possible shortcomings of the facilities and other issues.

When planning a training programme, the basic principles of adult learning must be taken into account. A typical training programme incorporates adequate breaks for reflection, discussion sessions to stimulate thought and maximize interaction, and practical exercises that relate to the theoretical knowledge given in the lectures. A training programme should not be too intensive and should include short sessions with an adequate number of short breaks in between. A sample training programme is shown in Figure I.1.1.

Figure I.1.1. A sample programme for a training workshop

Training Workshop Schedule

Day 1	
	• Arrival and meeting of participants and international resource persons • Registration • Welcome dinner
Day 2	
08.30 – 09.00	• Formal opening Welcoming address Opening address
09.00 – 10.00	• Overview of the training and pre-training evaluation
10.00 – 10.30	***Coffee break***
Session 1 – Current trends in Asia and the Pacific region and their implications for horticultural chain management	
10.30 – 11.15	• Lecture: Trends that impact on agrifood systems in Asia and the Pacific region
11.15 – 12.00	• Lecture: Consumer trends in Asia and the Pacific region
12.00 – 13.00	***Lunch break***
Session 2 – Organizational strategies to enhance competitiveness in horticultural supply chains	
13.00 – 14.30	• Lecture: Understanding modern horticultural supply chains
14.30 – 15.00	***Coffee break***
15.00 – 16.30	• Practical 1– Meeting the consumer and observing consumer behaviour (visit to markets) • Discussion session and data analysis • Giving feedback from the day's activities

Day 3	
Session 2 – *continued*	
08.30 – 09.15	• Lecture: Integration of small farmers into horticultural chains in Asia and the Pacific region
09.15 – 10.00	• Lecture: Traditional and modern marketing channels for horticultural produce
10.00 – 10.30	***Coffee break***
10.30 – 14.00	• Field visit 1 – Visit to fresh produce market (including lunch break)
14.00 – 14.30	***Coffee break***
Session 3 – Horticultural produce quality	
14.30 – 15.30	• Lecture: Quality and food safety
15.30 – 16.30	• Lecture: Technical dimensions of horticultural chain management to assure quality
16.30 – 17.00	• Giving feedback from the day's activities
Day 4	
Session 4 – Quality impact factors in horticultural chains	
08.30 – 09.15	• Lecture: Physiological factors
09.15 – 10.00	• Lecture: Microbiological factors
10.00 – 10.30	***Coffee break***
10.30 – 12.00	• Practical 2 – Microbiology
12.00 – 13.00	***Lunch break***
13.00 – 15.00	• Practical 2 continued
15.00 – 15.30	***Coffee break***
15.30 – 16.30	• Lecture: Agricultural inputs and practices
16.30 – 17.00	• Giving feedback from the day's activities
Day 5	
	• Field visit 2 – Visit to fruit orchard or vegetable farm
	• Discussion session
	• Giving feedback from the day's activities
Day 6	
Session 4 – *continued*	
08.30 – 09.30	• Lecture: Entomological factors
09.30 – 10.30	• Lecture: Processing water
10.30 – 11.00	***Coffee break and instructions for field visit***
11.00 – 15.30	• Field visit 3 – Visit to fruit or vegetable packing house • Discussion session and data analysis • Giving feedback from the day's activities
Day 7	
Session 5 – Handling operations to assure quality maintenance in horticultural chains	
08.30 – 09.30	• Lecture: Assessment of harvest maturity
09.30 – 10.30	• Practical 3 – Assessment of fresh produce quality
10.30 – 11.00	***Coffee break***
11.00 – 13.00	• Practical 3 continued
13.00 – 14.00	***Lunch break***
14.00 – 15.00	• Lecture: Harvesting
15.00 – 16.00	• Lecture: Packing house operations
16.00 – 17.00	• Coffee break and giving feedback from the day's activities

Day 8		
Session 5 – *continued*		
08.30 – 09.30	•	Lecture: Pre-cooling operations
09.30 – 10.30	•	Lecture: Packaging of fresh produce
10.30 – 11.00	***Coffee break***	
11.00 – 13.00	•	Practical 4 – Impact of handling
13.00 – 14.00	***Lunch break***	
14.00 – 14.30	•	Lecture: Specialized treatments to improve quality
Session 6 – Quality maintenance during storage and transport		
14.30 – 15.30	•	Lecture: Maintaining fresh produce quality during cold storage
15.30 – 16.00	***Coffee break***	
16.00 – 17.00	•	Lecture: Maintaining fresh produce quality during transit
17.00 – 17.30	•	Giving feedback from the day's activities
Day 9		
Session 6 – *continued*		
08.30 – 10.30	•	Practical 5 – Impact of ineffective cold chain management using pre-stored produce
10.30 – 11.00	***Coffee break***	
Session 7 – Effective monitoring in horticultural chains		
11.00 – 12.00	•	Lecture: Traceability
12.00 – 13.00	***Lunch break***	
Session 8 – Logistical operations in horticultural chains		
13.00 – 14.00	•	Lecture: Logistical operations
Session 9 – Infrastructural support systems for horticultural chains		
14.00 – 15.00	•	Lecture: Transport systems
15.00 – 15.30	***Coffee break***	
15.30 – 16.30	•	Lecture: Packing houses
16.30 – 17.00	•	Giving feedback from the day's activities
Day 10		
Session 9 – *continued*		
08.30 – 09.30	•	Lecture: Cold storage
Session 10 – Good practices in selected horticultural chains		
09.30 – 10.30	•	Lecture: Good practices in selected fruit supply chains
10.30 – 11.00	***Coffee break***	
11.00 – 12.00	•	Lecture: Good practice in selected vegetable supply chains
12.00 – 13.00	***Lunch break***	
13.00 – 14.00	Overall discussion and evaluation	
14.30 – 15.00	Closing and distribution of certificates of participation	
15.00 – 16.00	Farewell treat	
Day 11 – Homeward bound		

Planning the practical exercises

Practical exercises must fit in with the training environment. The trainer must plan ahead and ensure that the required facilities and materials for the practical exercises are available.

Excursions to fresh produce markets (supermarkets, wet markets and/or fruit and vegetable retail shops) and farms that are linked to post-harvest facilities (e.g. packing houses, storage facilities) should be included in the programme. During the excursion, participants should be required to perform short tasks that allow them to link their observations to the theoretical components of the programme. Tasks of this type keep trainees stimulated and give them time to reflect and consider their own experiences. A certain degree of flexibility must be exerted whenever available facilities are less than ideal.

Tasks can be assigned for discussion in either horizontal or vertical groups (see below). By using either horizontal or vertical groups, the trainer can obtain different levels of input and areas of focus. In certain cases, a group opinion is important whereas with other tasks a cross-section of opinions from various disciplines would be more appropriate. Regular discussion sessions are valuable in forcing participants to consider their own situations and to reflect on new knowledge acquired.

A balance of different personalities is essential for optimum interaction within the groups. Too many strong, dominant participants may suppress inputs from less vocal participants.

Horizontal groups – groups of people coming from different fields of experience and having different levels of responsibility, i.e. individuals from government, industry, the export sector, associations or cooperatives, commercial and small-scale farmers.

Vertical groups – individuals from more or less the same background, e.g. a group comprising small-scale farmers, or one made up of academics or government officials.

Planning the assessment process

An assessment of the approaches to be used during the programme should be determined. In certain cases an approach involving continuous assessment in an informal manner may be more effective than the administration of an end-point examination, which can be stressful for participants. A range of assessment formats can be used, with those best suited to the needs of each specific audience being selected. Continuous assessment of trainer participation throughout the programme will necessitate the assistance of support staff. A combination of assessment tools is often best and makes the process less stressful for the organizers and the trainees.

Selecting the trainers

The trainers or resource persons must be selected on the basis of their experience and communication skills. The practical experience of a farmer or retailer is often more effective than theoretical presentations by academics. Resource persons must be selected well in advance of the training programme. Arrangements must be made for their formal invitation, remuneration and recognition. If required, special transport and accommodation arrangements must be made. Resource persons must be familiar with the venue, the audience and what is expected of them. They may be required to submit brief curriculum vitae (CV) for record purposes and for use in introducing them prior to their presentation. Each trainer must be thanked and perhaps awarded a simple token of appreciation for his/her input and time. A courteous thank you letter afterwards is essential. Audience feedback (written) is also helpful for improving future presentations.

Selecting the training venue

When deciding on the venue for the training programme, the following must be considered:

- training budget;
- cost of in-house versus out-sourced training;
- purpose of the training programme
  to train small-scale farmers in rural areas, or
  to train the public and/or the private sector;

- the duration of the programme;
- availability of electricity (where electricity is not available such as in rural areas, provisions for use of papers, posters and clipboards, or a generator have to be prepared);
- number of participants;
- cost of transport, accommodation, meals and refreshments; and
- access to administrative support (e.g. fax and photocopy machines and so on).

Selecting the participants

Selecting the correct combination of participants at various levels of involvement in the horticultural supply chain could be an effective mechanism for stimulating active participation in the training programme. An alternative approach is to offer the training to a defined group of stakeholders such as small-scale farmers. In such circumstances, the resource persons must come from the various sectors of horticultural chains and contribute in their fields of specialization.

Assessing the training requirements

Prior to selecting the participants, the trainer must have some knowledge of the background of the trainees and their expectations. This can be done through a simple survey using a basic needs assessment form. In situations where the trainees make up a diverse audience (e.g. a mix of exporters, transporters, government officials etc.) a form such as that shown in Figure I.1.2 would be appropriate for this assessment, whereas in situations where trainees constitute a single target group, the form shown in Figure I.1.3 would be more appropriate. The responses should be analysed prior to the training programme in order to facilitate targeting of knowledge transfer, defining the level of details that should be included in the course, and identifying the most relevant information.

Based on the analysis of the completed forms, specific learning objectives can be formulated by the trainer. The following should, therefore, be considered prior to planning the training:

- purpose of the training programme;
- background of the participants and their knowledge of the subject;
- learning the goals of the participants;
- participants' interest in the subject; and
- commonalities shared by the participants.

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Figure I.1.2. Sample form for the assessment of training requirements of a diverse audience

What are your expectations of the course?

Please complete the form and answer all questions

First name: ....
Family name: ....
Job title: ....
Company/institution that you work for: ....
Contact details, e-mail: ....
Tel no: country code …………… Area code …………… Number ....
Fields of specialization: (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? ....

Expectations and experience:
What are your expectations of this training course?
....
....
....
....
....
What do you plan to do with this information once you return to your 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? Beginners ……… Intermediate ……… Higher ....
Do you think you need a test at the end? Yes ……… No ……… If yes, why? ....
How would you like to be assessed in terms of absorbing the knowledge?
....
....
Any suggestions for the trainer in terms of your expectations?
....
....
General questions:
Do you use your e-mail regularly? Yes ……… No ……… If yes, how often? ....
Does your company have a Web site? Yes ……... No ……... If yes, have you visited it? Yes …….. No ……..

Figure I.1.3. Sample form for the assessment of training requirements of a single target group

What are your expectations of the course?

Please complete the form and answer all questions

First name: ....
Family name: ....
Contact details: ....
Do you have a cell phone? Yes ……… No ………
If yes, what is the cell phone number: ....
What are your highest qualifications? ....
What language(s) do you speak? ....
Do you own a farm? Yes ………… No ………… **If not, are you leasing one?** Yes …………No ....
What is the average size of the farm?:
> 20 ha …………; 10–19 ha …………; 5–9 ha …………; 2–4 ha …………; 1 ha …………; 0.5 ha ....

Which crops do you cultivate on the land?
....
....
....

What fields are you interested in? (tick all applicable):
Horticulture …………….. Post-harvest technology …………… Post-harvest pathology ....
Microbiology …………… Post-harvest physiology …………… Agricultural economics ....
Education …………… Others ....
What information should the course focus on? (tick all applicable):
Microfinance ………… Business transactions ………… Pesticide spraying ………… Management ....
Pesticide storage and usage ……….. Disease and pest names ……….. Control pests and diseases ....
Quality aspects ……… Harvesting methods ……… Quality assurance ……… Transport issues ....
Food safety …………… Export initiatives …………… Export markets …………… Processing ....
Others …………………… Please specify ....

Expectations:
What are your expectations of this training course?
....
....
....
What do you plan to do with this information once you return to your country?
....
....
....
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? Beginners ……… Intermediate ……… Higher..................
Do you think you need a test at the end? Yes ……… No ……… If yes why? ....
The organisers would like to know to what extent the participants have absorbed the knowledge imparted during the training course, how do you think they should find out? End of course written test? ....
Other? …………….. Please specify ....
....
....
Any suggestions for the course presenters:
....

Section I

Module 2 – Implementing the training programme

Learning outcomes

The learner should understand how to implement a training programme effectively.

Introduction

Successful knowledge transfer and meeting the expectations of the trainees is largely dependent on how the training programme is implemented. Attention must be given to details that can impact on the flow and quality of the programme. Development of a basic planning schedule helps to ensure that details are covered and any last minute changes and rushing around are avoided. Regular meetings with the training staff ensure that arrangements are carried out according to schedule. A basic programme planning chart, such as that shown in Figure I.2.1, can be used to ensure that all involved in the implementation of the training are reminded of their tasks.

Delivering the lectures

When preparing for lectures, visual materials must be selected according to the needs of the training group. Visual materials can also be included to adapt the presentation to local conditions. When planning a lecture, 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. A time frame of at least ten minutes must be included for discussions between lectures. Sessions should be conducted in two-hour blocks and must introduce tasks, practical exercises or group discussions to maintain the interest and attention of the trainees.

During the delivery of lectures, the lecturer must:

- demonstrate an understanding of the learner's situation;
- create a caring and concerned environment;
- use a variety of instructional methods and materials that are suitable for the audience;
- exhibit enthusiasm and passion for the task; and
- develop a positive and participatory approach within the group.

Individual participants should feel responsible/accepted/understood, as an important part of the process, and that their opinions are being taken into account.

Consideration must be given to factors that impact upon the effective uptake of information and the ability to learn. The training of adult learners can be highly challenging, given that they often have different levels of:

- current knowledge and interest in the topic;
- confidence;

- capability, age and attitude;
- educational background, previous training and experience;
- capability to understand complex situations; and
- enthusiasm and ability to focus.

Figure I.2.1. A sample programme planning chart

Date	Planned activity	Responsible	Completed
Pre-planning			
	Plan training schedule for the year		
	Develop marketing brochures for the training		
	Discuss training initiatives with public and private sector		
	Determine training needs		
	Establish course attendance fees		
	Draw up course attendance forms		
	Draw up needs assessment forms		
Planning workshop			
	Arrange first workshop		
	Invite participants or finalize attendant list		
	Send course attendance and needs assessment forms to participants		
	Send reminders to return forms		
	Arrange venue		
	Arrange meals and teas		
	Arrange accommodation for participants		
	Arrange for transport if required		
	Invite selected speakers		
	Send formal invitations to selected speakers		
	Arrange accommodation and transport for speakers if applicable		
	Plan training material package		
	Analyse needs assessment and consider it with final preparation of slides		
	Select slide series		
	Select practicals		
	Draw up training programme		
	Arrange for opening or welcoming speaker		
	Arrange staff to help with administration and finances		
	Arrange staff to help with practicals		
	Arrange staff to help with the flow of the workshop, to chair sessions, etc.		
	Prepare for practicals		
Workshop arrangements			
	Get training material ready for the workshop		
	Papers, pens, name cards, files, manuals, copy of slides		
	White board marker, sticky tape, overhead projector or data projector		
	Get gifts for speakers		
	Arrange participation certificates		
	Analyse feedback forms		
	Give feedback to presenters		
Post-workshop arrangements			
	After workshop send thank you letters to speakers		
	Follow up on participants to determine if knowledge has been implemented		
	Record data on participants		
	Archive training material		
	Itemized statement of expenditure		
	Audited statement of accounts		

The effective uptake of information by trainees is dependent on the nature of the information being taught, the instructional methods and techniques used, the capability, enthusiasm and attitude of the trainer, the breadth of scope covered by the lectures, and the practical exercises included within the programme. Knowing and understanding the adult learning process is vital in developing and implementing effective training programmes. Thus, during the development of training material, it is essential that the trainer keeps in mind that the trainees are independent, have an extensive variety of real life experiences, are mostly concerned with their own immediate problems, and enter learning situations with their own goals, motivations, needs and experiences.

The trainees learn better "by doing" and if:

- they are involved;
- the topic relates to their own needs and daily activities;
- materials are structured to meet their specific needs;
- training is informal and given in an environment that is familiar to them;
- materials are presented through a variety of methods integrated with real life practical examples and visual demonstrations;
- subjects are explained well and text is supported with visual illustrations or drawings;
- activities and tasks are clearly structured, simple and relate to subjects, objects and examples familiar to them; and
- they are not tested or put under pressure.

Delivering the practical exercises

The method of instruction must consider the basic level of uptake of different forms of training. Visual images are remembered more effectively than words and adults prefer "how to" and "hands-on" exercises. The trainees therefore learn better when given opportunities to apply, explain and practice what they have learned or when working in groups.

Wrapping up the training

A formal closure is a prerequisite of a well-organized training programme. It is usually done after the participants have completed the written evaluation of the training. During the closing session, the importance, activities and outcomes of the training are recapitulated, impressions are verbalized, post-training activities and responsibilities are agreed upon, and the participants are formally congratulated.

The Chair of the training programme or his/her representative presides over the closing session. This individual may reiterate the importance and different activities of the training, share observations and underscore the trainees' expected activities in their respective countries as a direct application of experiences gained from the training.

The trainees are then given time to provide their impressions of the training. This has to be made known to them before the closing session to allow them ample time to prepare for a more encompassing feedback. If time permits, all participants can give oral feedback, otherwise a representative or two can deliver feedback on behalf of the group.

Finally, the participants are formally awarded a certificate of participation bearing the name of the participant, the date, venue, title and sponsors of the programme.

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Section I

Module 3 – Assessment and documentation of the training programme

Learning outcomes

The learner should understand how to:

- assess the effectiveness of the training programme; and
- keep track of participants and their post-training activities.

Introduction

Training assessment is important since it helps the trainer to reflect on the training programme and to continuously improve the materials, visuals, practical exercises and presentation of information. Trainers can ensure that information is continuously updated by using an effective assessment form, which can be adapted to the target group being trained. Assessment provides trainees with an opportunity to question and to be aware of what they have learned. It also gives them confidence in applying the skills they have acquired and helps them to analyse the way in which they have acquired knowledge during the training programme.

Obtaining feedback

An effective mechanism for obtaining feedback is 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 I.3.1.

Providing feedback

Providing feedback throughout and at the end of the course is also essential. In cases where practical tasks are assigned, it is essential that a summary of results and findings is given. Different groups must be given the opportunity to provide feedback on their discussion sessions at the end of each day. Prior to the discussion of new activities, the day should start with a reflection on the presentations, discussions and practicals of the previous day.

Credit can be given for group discussions 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 programme 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. If a test is given, it is essential that feedback be provided within a few days of completion of the course.

Figure I.3.1. Sample form for evaluating the training

Training evaluation

Training of trainers on horticultural chain management in Asia and the Pacific region
2–13 March 2008, KMUTT, Bangkok, Thailand

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 (hands-on activities)					
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 "training the trainer" course					
Practical application of the course					
Meeting 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:

....

....

....

Keeping record

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. In certain cases, attendees, suppliers, exporters or their companies might request proof of course attendance at a later date. Keeping a databank of training programmes held can therefore aid in the efficient logistical management of events.

Staying in touch

It is essential to follow-up after the course and to find out if any technology or knowledge has been implemented. The level of uptake of knowledge during the training and application of such knowledge after the training will reflect the effectiveness of the training programme.

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SECTION II

Current trends in Asia and the Pacific region and their implications for horticultural chain management

Section II

Module 1 – Trends that impact on agrifood systems in Asia and the Pacific region*

Learning outcomes

The learner should:

- develop an appreciation of the factors that currently impact upon agrifood systems in the region;
- develop an understanding of opportunities for small-scale horticultural producers, processors and exporters in Asia and the Pacific region; and
- develop an understanding of actions that must be taken in order to maintain competitiveness within the horticultural sector.

Introduction

Globally, fresh produce markets have changed dramatically over the last two decades. Positive economic growth in much of Asia and the Pacific region has led to shifts in consumer demand, technological change in marketing and strong retail purchasing power. At the same time, consumer preferences have changed with an increased awareness of food safety, growing consumption of fresh produce and demand for a variety of familiar and unfamiliar produce items, organic produce and convenience foods. Consumers are increasingly concerned about the environmental and social conditions under which their food is produced. At the retail level, consolidation has occurred at a rapid pace as large supermarket chains have merged. This has resulted in changes in relationships among producers, wholesalers and retailers.

This module discusses current changes in agrifood systems in Asia and the Pacific region and their implications for horticultural chain management. It outlines strategic actions to be taken in order to maintain competitiveness and ensure the continued access of small-scale actors to local, regional and international markets.

Trends in economic growth and in horticultural trade

Asia and the Pacific region is culturally rich, progressive and is becoming a focus of attention for its income growth and economic integration. Over the past five years, economic growth of the region as a whole averaged about 7 percent per annum. This average is shared among the rapidly growing East Asian countries, the strong emerging economies of Southeast Asia, the smaller island economies of the South Pacific, the giant economies of China (10.7 percent growth in 2006) and India (9.2 percent growth in 2006), and the somewhat lagging economies of the Asian subcontinent. The level of growth achieved by individual countries is affected by the actions of other countries in the region.

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* K. Chan & R. Rolle

Japan leads Asia as the second largest economy in the world, with a GDP per capita of US$33 100 in 2007. As a rich and developed country, Japan is able to set standards for its Asian neighbours to benchmark its high farm productivity and efficient logistics and distribution systems for fresh horticultural produce. Japanese consumers have very high expectations for product packaging, which is considered to be among the best globally. The Japanese market is also very demanding in terms of requirements for quality, safety and handling standards for fresh produce.

The other East Asian economies of Taiwan, South Korea and China combined, accounted for a GDP of US$3.54 trillion in 2007, or 31.5 percent of the output of Asia and the Pacific region. Taiwanese and Koreans are affluent consumers of fresh produce and much of their fresh produce supplies are imported from Southeast Asian countries.

China floods the European Union (EU) and United States fruit markets and many Southeast Asian markets with its horticultural outputs, yet at the same time China imports a large amount of horticultural produce from Southeast Asia to feed its very large population – a population with rapidly growing affluence. China's large population and strong income growth will continue to create demand for very large quantities of fresh produce from neighbouring Asian countries.

The "tiger" economies of Indonesia, Malaysia and Thailand started their growth path from the mid-1980s with the microprocessor industries. This growth path then spilled into other manufacturing industries and though briefly interrupted by the Asian financial crisis of 1997/1998, has continued to progress.

The emerging economies of Southeast Asia, notably Viet Nam, are also recording strong growth. Increasing levels of education, the opening up of trade, the transformation of cities, together with their increased economic wealth have produced a new growing group of discerning middle-class consumers who aspire to modern lifestyles and modern consumption habits and who demand high quality imported produce.

India currently leads the Asian subcontinent having had an average growth of about 7.1 percent per annum for the past five years. Whereas in the past, Indian horticultural trade policy had not been sufficiently open, India now has begun to relax and open its doors to foreign investment in both the retail and import sectors.

Other countries in the region, namely, Bangladesh, Nepal and Sri Lanka, despite their individual political distractions, have only enjoyed modest growth. Although this modest growth may not encourage a dramatic change in fresh produce consumption in these countries, the trade and export of fresh produce from these countries to neighbouring India will continue to grow in volume and sophistication. This trade will provide considerable economic growth opportunities for these countries.

Traditional horticultural exports from the region to European and North American markets are nearing maturity. These two very large and affluent markets are currently being fully supplied on a year-round basis with fruits and vegetables from every corner of the world (Latin and South America, Australia), including their own increasing production. For the many developing countries in Asia and the Pacific region, accessing these markets is a great challenge.

Many Asian countries have signed bilateral Free Trade Agreements with the EU, Japan, the United States and China. The specificity of these bilateral trade agreements generally covers only a limited range and quantum of fresh produce and has precise definitions for produce quality, sanitary and phytosanitary Standard (SPS) controls, food safety measures and produce traceability and origin. These trade specifications force trading nations to pay greater attention to supply chain approaches and indeed present new challenges for horticultural producers. Low cost, low quality, bulk production approaches are no longer acceptable for horticultural production and export. Good Agricultural Practices, intensive cultivation, high productivity and competitive pricing are now required. It is now a buyer's market and the terms of trade for horticultural produce are dictated by the requirements of the consumer.

The sheer size of the Chinese market and its production capacity has integrated much of the trading system in Asia and the Pacific region, both in the presence and absence of bilateral trade agreements. As in the case of India, China has had a great pull for integrating trade with its neighbours – it is thus difficult to discount trade with China today. Meanwhile, trade with China no longer means low quality, bulk production and cheap exports. With membership in the World Trade Organization (WTO) and targeting of its exports to Japan, the EU and North America, China seeks to push itself up the value chain in produce outputs and production processes. Neighbouring countries will ride on this trend and will, in turn, benefit from the process.

Drivers of change in the horticultural sector

Rising per capita incomes

Rising per capita incomes in the emerging economies of East and Southeast Asia over the last two decades have created a growing middle class population primarily in urban areas and have brought about changes in a number of areas:

- *Consumer tastes* – Lifestyle changes brought about by improved economic conditions have had an impact on eating habits. Exotic and imported foods as well as health foods and organic foods are now in high demand by consumers.
- *Shopping habits* – With more time spent in the work place and less time available for food preparation, the demand for fast food, convenience food and pre-packed foods continues to grow. Many middle class earners in Asia are more likely to shop in supermarkets which offer a wider variety of goods than in traditional open or wet markets and high street retail shops. In addition, because of more amenities at home (e.g. refrigerators and microwave ovens) shopping trips are now fewer than before.
- *Consumer perception of foods* – The consumption of sweet potatoes typifies changing consumer perceptions of foods. Once considered a poor man's food in China, now sweet potato is gaining popularity among middle class consumers.
- *Food choices* – With increasing disposable incomes and the availability of a variety of foods in local markets, the budgetary allocation of consumers to fruits and vegetables is steadily increasing. Consumers are also increasingly becoming aware of proper nutrition. The over-consumption of food is in some cases an issue.

Urbanization

According to UNESCAP, the region is experiencing rapid urbanization at a rate of 2.3 percent per year. This rate is twice as high as the total population growth rate. Projections, according to UNESCAP, are that urban population across the region will account for 52 percent of total regional population by 2025. Much of this increase will take place in South Asia.

Large urban populations create large domestic markets for horticultural crops and the pressure to improve efficiency in production as well as in the delivery of produce to consumers. As urban land encroaches outwards, the cost of land and the cost of production increase. The greater the distance between the fresh produce farm and the retail market, the higher the delivery cost and the longer the supply chain. If additional value is accrued to the produce (for example, through packaging), the cost of produce to the consumer is likely to increase.

Trade liberalization

Over the last few decades, many countries have removed entry barriers into their markets through the privatization of public enterprises and have opened up monopolized sectors to competition and removed or reduced regulations and restrictions.

Growth in world trade has resulted in an increase in international financial transactions and capital flows. One of the most important types of capital flows is Foreign Direct Investment (FDI), which refers to the long-term investment by an enterprise in one country into an enterprise in another. Many developing countries in Asia have improved their domestic investment climates, education systems, skills, infrastructure, regulations and institutions and are opening up their markets for investment. Japanese authorities for example, are now willing to allow the limited importation of horticultural produce and are now able to invest in farms in Indonesia and Viet Nam. Fresh produce from these farms is exported back to Japan, generating income for these developing countries. FDI flows from outside of the region have led to a growth in the number of supermarkets across the region also.

With increasing globalization in trade, the notion of traditional markets and traditional sources has become less meaningful. Produce is sold to any market that is willing to pay for it. At the same time, consumer markets increasingly seek out horticultural producers that have the ability to grow and ship at the most competitive price.

Technological advances

Information and communication technologies (ICT) such as the Internet and cell phones are becoming more widespread across the region and logistics and transportation systems are constantly being developed and improved to service growing trade and to respond to the changes that are taking place in the retail sector with growth in supermarkets. These systems have also made it possible to source and to transport highly perishable fruits and vegetables rapidly and efficiently between the northern and southern hemispheres, east and west of the Pacific Ocean.

Large state-of-the-art packing houses are now being constructed by giant multinational fruit and vegetable corporations in the vicinity of producer farms in developing Asia. These farms aim to assure quality control, reduce wastage and shorten the delivery time from farm to table. Their produce outputs are marketed under hygienic conditions in selected and packed cartons. Minimally processed and ready-to-eat fresh produce items are also produced at these packing houses and are directly shipped to retail outlets. International airlines and shipping lines offer the best freight rates and the most direct routes to overseas markets.

Scientific, technical, logistical and managerial capacities allow fresh produce to maintain its quality during transportation to distant markets. Cold chain systems and controlled atmosphere containerization have made it possible to transport highly perishable fruits and vegetables rapidly and efficiently between the northern and southern hemispheres, east and west of the Pacific Ocean. Developed markets in Europe, America and Japan are now able to consume temperate and tropical fresh produce on a year round basis. At the same time, improvements in the management of marketing information help to maximize the shelf-life and quality of produce.

Field agronomic practices developed by research institutions in, for example, Europe, America and Japan yield highly productive and profitable results. The most advanced seed producer companies globally are located in these developed countries also. In order to stay abreast of developments in agronomic practices, developing Asian farmers will need to learn and adopt new practices and technologies and maintain close networking relationships with international corporations and research institutes.

Population dynamics

During the past ten years, the population of Asia and the Pacific region has increased from 3.5 billion to 4 billion in 2006. This represents over three-fifths of the world's population. The region's population is growing at a rate of 1.1 percent per year and is expected to reach 4.7 billion by 2025. Agrifood systems must be expanded and strengthened to serve the food requirements of the present and future generations.

The ageing and elderly is a growing segment of the region's population. Projections are that by 2050, 17.5 percent of the region's population will be over the age of 65. Approximately 21 percent of Japan's current population is now over the age of 65. This figure is expected to increase to 30 percent by the year 2030. This effectively means that by the year 2030, one out of three Japanese will be at least 65 years old. Similarly, by 2025 more than 15 percent of China's population will be of this age group. Food consumption patterns and requirements of this segment of the population are different from those of the younger high-income consumers. Fruits and vegetables demanded by that segment must be of soft texture, easily digestible, healthy and high in fibre. It will, therefore, be necessary for producers to understand these requirements and cater to the specific needs of that market segment.

Changing lifestyles

An increasing number of working women has generated growth in the demand for foods in a convenient format. This has, in turn, led to growth in the demand for pre-prepared, pre-packaged and pre-cut fruits and vegetables, as well as to increased eating away from the home in fast-food restaurants and similar venues.

Asian households have become smaller as a result of the attainment of higher levels of education, greater work pressure and greater involvement of women in the workplace, not to mention the population policies of some countries (e.g. the one-child policy in China and the two-child policy in Viet Nam). Preparation and marketing of fruits and vegetables must, therefore, consider the household size of target consumers. Furthermore, credit cards are used increasingly by consumers in supermarkets and this puts these establishments at an advantage over convenience store chains, wet markets and street vendors.

Safety and quality consciousness of consumers

Consumer awareness of food quality and safety issues in the region has grown tremendously. Asian consumers increasingly demand high-quality, pre-packed, even pre-cut produce that is safe and of hygienic quality. They also want to be served as preferred customers and seek choices between brands and at attractive prices. At the same time, much more needs to be done within the region to educate and promote awareness on food safety and quality among producers, handlers and consumers.

In response to growing consumer concerns for food safety, public sector food safety regulations, private standards, and technical protocols and systems such as Good Agricultural Practice (GAP), Good Manufacturing Practice (GMP) and Hazard Analysis and Critical Control Point (HACCP) continue to be introduced into the fruit and vegetable supply chains in the region. Special systems such as the *Q system* in Thailand and Malaysia's *Best in Malaysia* have been developed to address these issues. Many supermarkets and importers of fresh produce also require that a traceability system be put in place to assure produce safety.

Standards are also being developed by multiple chain supermarkets and other private-sector companies. Although these standards are generally compliant with public sector regulations, they are designed to differentiate the private sector entity from its competitors and to facilitate supply chain coordination. This trend is widespread in the European Union, a key destination of horticultural produce and value-added products sourced from Asian countries. Standards developed by companies in the EU include Tesco's *Nature's Choice*, Carrefour's *Filière de Qualité* and Loblaw's *President's Choice*.

Groups of firms or business associations in the EU have also developed private standards; the most widely applied being the GlobalGAP standard which was developed by an association of fresh produce importers and retailers. The GlobalGAP standard provides for the use and application of pesticides and chemicals and the environmental impact of farming systems, and labour standards. It also allows for the interpretation of guidelines on a regional basis. Many Asian countries that have strong export markets in Europe have already set up national standards and have benchmarked them to the GlobalGAP standard.

Sanitary and phytosanitary standard (SPS) quarantine restrictions are strongly enacted by the governments of the United States, Australia, New Zealand and Japan. These quarantine restrictions are internationally agreed science-based standards and conditions that govern the physical movement of horticultural produce across borders.

Impact of trends

Income growth and urbanization will continue to generate demand for fresh fruits and vegetables in Asia and the Pacific region. With the liberalization of FDI in the retail sector, capital inflows from developed countries such as Europe and the United States will further increase and supermarkets will continue to proliferate. Growth in the number of supermarkets will necessitate the development of requisite retail management systems as well as logistics systems and technologies.

Supermarkets as a predominant player

Since the 1990s, supermarkets have assumed an increasingly important share in food retailing in Asia. Domestic retail supermarkets in many Asian countries currently compete among themselves and with international supermarket chains. Supermarkets are primarily very large chain stores that sell large volumes of both food and non-food items at low-cost and low-margins. Although in the past they targeted high income consumers in urban centres, they now target middle and lower middle income consumers and are spreading into traditional local market areas, edging out small grocery stores and fresh fruit and vegetable stalls.

Given their ability to procure large volumes of produce, supermarkets command considerable strength and bargaining power. Large supermarkets generally source their fresh produce supplies from large farms that have the capacity to consistently satisfy their requirements for volume, safety and quality at competitive prices. They are increasingly involved in the accreditation of fresh produce suppliers for Good Agricultural Practices and Good Manufacturing Practices. These preferred suppliers must demonstrate their competence in farming, the use of pesticides and chemical inputs as well as in the use of tracking and tracing systems for their fresh produce outputs. The cost of conforming to all of these practices must, however, be fully borne by producers. Given the inability of many small growers to comply with these requirements and to meet the high cost of certification, commercial farmers are, in general, the major suppliers of large supermarkets.

Many supermarket chains also practice corporate social responsibility by returning benefits to farming communities through farm technical training and community services projects that involve both private sector and government agencies. Supermarkets are also increasingly involved with environmental protection programmes and standards that can be monitored and controlled by supply chain stakeholders.

Consolidation of local and multinational supermarkets

The past five years have witnessed a frenzy of consolidation of buying or the establishment of new stores by multinational supermarket chains in the emerging economies of Asia. A growing number of foreign-owned (European and American) supermarkets have become engaged in joint ventures with local and small supermarkets, given the inability of many of these local supermarket chains to compete with foreign-owned companies that possess vast financial resources, management technologies, electronic inventory control systems, purchasing power capacity and the ability to compete on pricing. Many large supermarkets are also engaged in the export of fresh produce to neighbouring countries, thereby increasing their control over the fresh produce supply base.

Major supermarkets are also expanding into other retail store types – specialty stores, discount stores and convenience stores. The intention is to integrate horizontally and cover a wider spread of the consumer base. All of these stores are located in the main cities and the suburbs. With the large Asian urban population providing a ready market, this expansion will continue for some time.

Implications for stakeholders

The increased demand for high quality, safe and hygienic fruits and vegetables creates opportunities for trade, value adding, niche marketing and product specialization. However, to tap into these opportunities successfully and competitively, skills and capacities must be developed to manage quality, assure safety, and manage information flows within horticultural chains. Education and infrastructure must be improved and an open market system must be developed. The mindset and attitudes of producers must move from subsistence production, planned production and subsidized production, into profitable and competitive production. Produce specialization, trade specialization and industry innovation will be required and competitive, innovation systems will have to be developed by traditional rural farmers. Farmers will now be required to be more sensitive toward the needs of consumers for their production and marketing strategies and must take new approaches toward satisfying consumer demand. These approaches could include the introduction of new varieties of different colours, flavours, aromas and shapes and which fetch higher prices. At the same time, it will also be necessary for producers and retailers to make every effort to advertise and promote fresh produce in a manner that is appealing to the growing numbers of affluent consumers in the region.

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Suggested methods of instruction

Lecture using visuals or handouts and discussion.

Time frame

45 minutes.

Section II

Module 2 – Consumer trends in Asia and the Pacific region*

Learning outcome

The learner should:

- develop an appreciation of current consumer trends that have an impact on the fruit and vegetable sector in Asia and the Pacific region.

Introduction

The emerging economies of Asia and the Pacific region are riding on a wave of economic confidence. Economic growth in the region has produced a large number of middle class individuals mainly in urban areas with high disposable incomes, optimism for continued income growth, and high confidence in their job prospects, making them a very strong consumer force. With their increased purchasing power, consumers in the region are increasingly demanding, shopping habits are changing, as are lifestyles and consumer perceptions of food. Asian horticultural markets will continue to be transformed by the requirements of these consumers.

This module reviews the major food consumption trends in Asia and the Pacific region.

Food safety concerns

Consumers in the region are concerned about food safety and often opt to purchase fresh food in modern supermarkets which uphold high standards of hygiene and food safety. Many supermarkets demand traceability systems from their fresh produce suppliers as a measure of assuring consumer confidence. At the same time, growing interest in attaining wellness through diet is fuelling interest and change in food demands, leading to increased consumption of non-traditional foods such as organic produce.

Several assurance programmes have been initiated in the region in order to address the food safety concerns and health consciousness of consumers. National programmes that promote Good Agricultural Practice (GAP) have been developed to assure quality and safety of fresh produce in domestic markets. These programmes aim to reduce the risks of producing and consuming products from chemically intensive agriculture and facilitate export market access. Meeting consumer demand for safety, convenience and quality has led to increased packaging, branding and labelling of produce by supermarkets.

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Demand for quality

The consumer base of specialty fresh produce shops in Asian cities continues to show a consistent growth trend. Supermarkets offer differentiated categories of produce quality. High quality produce is placed in selected locations of the shop floor, often in specialized packaging with labelling that identifies the origin of the produce and other information (e.g. nutritional labelling) that adds value. More affluent consumers often perceive highly priced produce to be of good quality. Many show a preference for fresh produce originating from more developed countries.

Demand for innovation and convenience

New varieties of produce and innovative products are increasingly demanded by both the customer (supermarkets) and the consumer. Seed companies have responded to consumer demand for innovation by producing improved varieties of planting materials as well as new sizes (e.g. baby vegetables), shapes (e.g. square watermelons), or colours of fruits and vegetables. Supermarkets have also responded to this trend by marketing exotic and rare produce varieties as well as through innovating in packaging. Bananas, for example, which were traditionally sold in 13 kg boxes found considerable consumer acceptance when packed in 3 kg boxes. Small packaging units offer many advantages over larger units. Indeed, there is a need for supply chain stakeholders to "think outside of the box" and to continually innovate.

Furthermore, the increasing pace of consumer lifestyles, has led to increased demand for produce in more convenient formats, e.g. fruits and vegetables in ready-to-serve and ready-to-eat formats, as well as in frozen and fresh microwaveable formats.

Demand for variety

Consumers often demand a range of produce options as well as variety (e.g. cherry tomatoes, salad tomatoes, cooking tomatoes) in terms of a specific produce category. Supermarkets are required therefore to respond to these requirements. Plant breeders and seed suppliers are also required to respond to this need.

Other food consumption trends

- *Demand for exotic foods* – Increased travel and tourism within the region as well as the influence of cable television has led to increasing demand for exotic produce items such as artichokes and cranberries which are not traditionally constituents of the Asian diet.
- *Increased expenditure on food* – Low interest rates in China and Malaysia, and access to credit cards and payment plans have increased household flexibility in spending on food.
- *Requirement for customization* – Customized products (e.g., individually packaged foods) that meet the preferences and lifestyle choices of single educated working women are also in demand.
- *Changes in produce sourcing* – Fresh produce is currently sourced on a global scale by supermarkets and produce importers. Countries can no longer rely on traditional business familiarity to compete. New players and new growers from different corners of the world are emerging as non-traditional sources of competitively priced produce that is of high quality. Rapid and efficient shipping technologies, low freight rates and communication technologies give new players equal or better competitive advantage.

Recommendations

As future trainers, it is important to understand the issues, stay informed of current developments, reformulate ideas and concepts in a language that is understandable by your audience, and use adequate training tools.

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Suggested methods of instruction

Lecture using visuals or handouts and discussion.

Practical exercise

Practical exercise II.1: Meeting the consumer.

Time frame

One hour for the lecture and discussion.
Half day for the practical exercise.

SECTION III

Organizational strategies to enhance competitiveness in horticultural supply chains

Section III

Module 1 – Understanding modern horticultural supply chains*

Learning outcomes

The learner should:

- develop an appreciation of the supply chain as a mechanism for delivering horticultural produce that meets market requirements;
- develop an appreciation of the key role players in supply chains and their functions;
- develop an appreciation of how the consumer drives modern supply chains; and
- develop an appreciation of the rationale for supply chain coordination.

Introduction

Market liberalization and growth in international trade have created export opportunities within the horticultural sectors of many countries of Asia and the Pacific region. At the same time, rapid urbanization and income growth in these countries have led to increased consumption of horticultural produce, thereby expanding the opportunities for small-scale producers. Tapping into these market opportunities is, however, contingent upon meeting a range of stringent requirements.

Fresh produce destined for both local and export markets must comply with private sector standards and codes of practice. Produce for export must also comply with the sanitary and phytosanitary standard (SPS) regulations of importing countries. Aside from these exigencies for produce safety and quality, requirements for guaranteed supplies and consistent volumes of the produce must be met. Thus, fresh produce can no longer be taken to the market on the off-chance that it will be purchased. Access to markets requires that produce be supplied through market-driven systems, in which market requirements known prior to production are used in specifying input quality as well as production and post-production practices.

This module discusses the horticultural supply chain, its evolution, and the coordination and flexibility required to effectively and efficiently respond to market requirements.

Fresh produce distribution systems

Several terms have evolved to describe the nature of food distribution systems. These include “supply chain”, “value chain”, “logistics” and “demand chain”.

A supply chain is a sequence of processes (decision-making and execution) and flows (material, information and money) that take place within and between different stages from production to final

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* S.C. Tongdee & K. Chan

consumption. It includes the producer, transporter, logistics service provider, retailer and consumer. Supply chains must be efficient and responsive to the needs of consumers.

Demand chains – In situations where supply chains are driven by consumer demand (demand pull) and product price, they are referred to as demand chains. Many supply chains today are demand-driven owing to the increasing quality and safety consciousness of consumers. The demand chain assumes a circular system, from the consumer to the producer. In the past, supply chains were linear systems based on supply push and cost value. Supply chain/demand chains can be assessed using Deming's Plan-Do-Check-Act (PDCA) cycle or analysing the strengths, weaknesses, opportunities and threats (SWOT).

In order to meet safety and quality expectations of consumers, each supply chain member must have a defined scope and clear goals and, most importantly, must enable the next chain member to perform subsequent activities. Each chain member should also have a simple *internal traceability system*. Linkages from farm to table can be established though *chain traceability systems*. Furthermore, chain members should consider that fresh fruits and vegetables are perishable, requiring proper temperature management and speed in delivery to the next stage in the chain and that produce of high volume usually commands low prices. Supply chains should also be adequately simple and flexible to respond to consumer concerns.

A *value chain* is an organized system of exchange from producer to consumer with the purpose of increasing the value and competitiveness of produce. It is about business linkages that promote collaboration among stakeholders in the chain (e.g. farmers, processors, market intermediaries, and exporters) to generate value for the consumer. A value chain is not a supply chain but must meet consumer demand and be competitive. The efficiency of a value chain can be determined on the basis of a cost/performance assessment or SWOT analysis.

A value chain is differentiated from a generic supply chain by the following characteristics:

- participants in the value chain have a long-term strategic vision;
- participants recognize their dependence on each other and are willing to work together to define common objectives, share risks and benefits, and make the relationship work;
- participants have a shared commitment to control produce quality and consistency; and
- participants have a high level of confidence in each other that allows greater security in business; this in turn facilitates the development of common goals and objectives.

Logistics is a part of the supply chain process that plans, implements and controls the physical flow and storage of goods, services and related information from the point of origin to the point of consumption. Logistics was previously regarded as a cost component of supply chains, but is now seen as a value-adding process that directly supports the primary goal of the chain. Logistical arrangements must be targeted toward meeting customer needs and complying with requirements imposed by stakeholders such as the government and the retailer. Logistical activities include inventory, transportation, the provision of other facilities (e.g. storage) and information, the effectiveness of which can be assessed by performing either a chain value analysis or SWOT analysis.

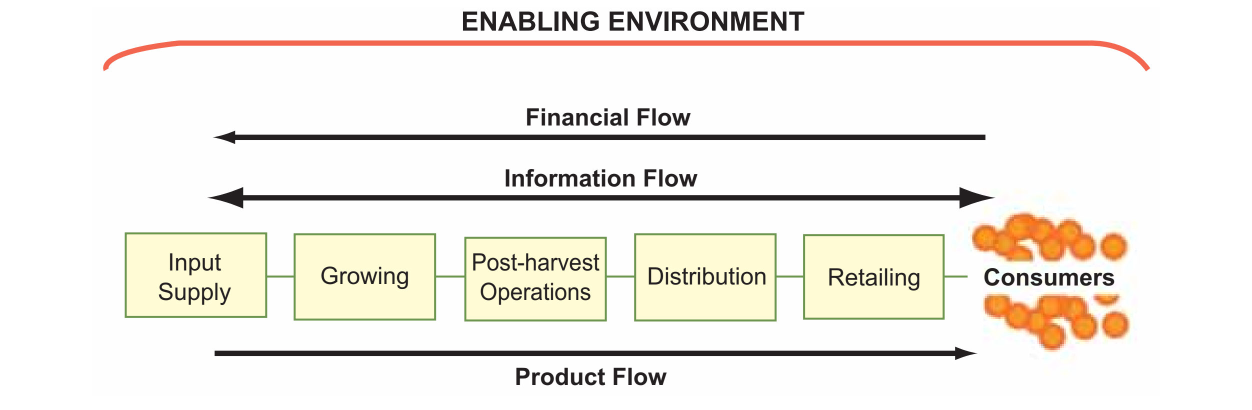
Horticultural supply chain

The horticultural supply chain is the entire vertical chain of activities from the supply of input (seed, fertilizer, chemicals) through production, post-harvest operations, distribution, and retail (Figure III.1.1).

Characteristics and evolution

Horticultural supply chains involve a fragmented loose chain of highly specialized tasks that are performed by individual participants (stakeholders) who are of different social, economic and cultural backgrounds. The weak link(s) determine(s) the strength of the supply chain. Along the chain, there is a dynamic and constant shift of bargaining power among members. With the emergence of modern trade stores (e.g. supermarkets), bargaining power and profit margins shift from sellers (producers, traders, exporters, importers) to buyers, and particularly the retailers.

Figure III.1.1. Key elements of the supply chain for horticultural produce



Key stakeholders

The *consumer* is the ultimate buyer and/or end user of produce in horticultural supply chains. A consumer may be a business, a household or an individual.

Narrowly defined, the *customer* in the supply chain is the grower, the trader, the processor, and the retailer. More broadly, the customer base includes all other participants who could contribute in the production and activities of delivering the produce to the consumer at an affordable price.

Flows governing optimal chain functioning

Three major flows within horticultural supply chains govern their optimal functioning (Figure III.1.1):

- *Flow of produce* – Fresh produce flows in one direction through the chain, from input supply (seeds, fertilizers, etc.) through to the retailer, who makes the produce available to consumers.
- *Financial flow* – Financial flow takes place in the opposite direction of produce flow, whereby payments are made to suppliers as produce moves from the producer through the various customers within the chain to the consumer. Financial flow is generated through the willingness of the consumer to pay for produce that meet their requirements.
- *Information flow* – Information flows in both directions throughout the supply chain. Market information on consumer requirements as well as information about what is demanded by customers at successive steps of the chain, moves from the retailer through the various customers to the producer. On the other hand, information about supply conditions and produce attributes travels from the producer through various customers within the chain. Information flow is very important in coordinating activities and practices at the different steps of the chain in order to assure that these activities and practices satisfy market requirements. It facilitates planning and coordination of supply. Information related to the identity of produce (e.g. origin, variety, orchard block from which produce is harvested), treatment at the packing house and handling (e.g. the temperature and relative humidity during distribution) through the chain, can be recorded and stored at the different steps of the chain. Stored data is used in providing traceability (tracing and tracking of produce) in the chain. Stored data may also serve during later verification of compliance with protocols such as those related to the application of Good Agricultural Practice (GAP) and Good Manufacturing Practice (GMP).

Enabling environment

Optimal functioning of horticultural supply chains, hinges upon a number of factors that are external to the chain, and which constitute an enabling environment (Figure III.1.1). These include:

- enabling policies and regulations;
- the infrastructural support base to facilitate chain operations; and
- business development support services, which include
  banks that provide loans

companies that provide market information
equipment hire services
logistics companies that transport and/or store produce
trainers and technical assistance providers.

Stakeholders and their interactions in value chains

Stakeholders in value chains in Asia and the Pacific region can be grouped into four categories: growers, logistics service providers, consumers and government or private sector. Produce quality trends are set by consumers, standards are developed by government agencies and international bodies and/or relevant private sector entities, whereas the grower creates or produces the desired produce, and the logistics service provider maintains and delivers the desired produce.

All customers within a value chain have a financial stake and can make decisions and bear liabilities that affect the value of produce outputs to the consumer. A major role of customers within horticultural value chains is, therefore, to assure the cost-effective implementation of activities within the chain that add value for the consumer. The use of hybrid seeds for improved yields and quality or improvements in cultivation techniques are examples of cost-reducing strategies that add value within horticultural chains. Given that the ultimate value of a produce item is measured by the price the consumer is willing to pay for that item, overall performance of the chain is dependent on how well individual customers within the supply chain interact with each other to create value. These interactions are measured by trade-offs, co-ordination and management skills.

Retailer/Consumer interactions

A growing percentage of the populations of Bangkok, Ho Chi Minh City, Jakarta, Kuala Lumpur and Manila procure their fresh produce requirements in supermarkets. Given their comparably higher incomes, these city dwellers have a preference for shopping in comfortable, organized and “modern” environments. They also demand a preferred customer status with requirements for high quality produce, a choice of attractively priced brands and show a preference for drawing close affiliations with large supermarket names.

In order to satisfy the requirements of regular consumers and to entice new consumers, supermarkets regularly conduct sales promotion campaigns through the development of promotional materials such as newspaper advertisements, leaflets and flyers to inform households of their price offers on fresh produce. Supermarkets also use special offers on fruits and vegetables as a means of attracting consumers. Although the margins on fruits and vegetables are small, volumes purchased generate large profits in other departments.

Supermarkets also engage in efforts designed to gain consumer loyalty. To this end, supermarkets build their household brand names and offer special consumer privileges. Brand names such as TOPVALU of Aeon Jusco, CQL of Carrefour and TESCO Value, are examples of household brand names in Malaysia.

Preferred consumer membership cards are also issued by supermarkets in order to foster closer relationships with consumers. These cards bear personalized identification and provide benefit in the form of privileged discounts and rebate gift vouchers. Local famous entertainers are often used as promotional ambassadors for supermarkets.

Retailer/Supplier interactions

One measure of the strength of a supermarket is how well it is served and supported by the supplier. Supermarkets value an intimate long-term relationship with their suppliers given the costly repercussions of an interruption in their supplies. Efficiency, consistency and reliability are important requirements of supermarket value chains. In situations where good supermarket/supplier relationships exist, both partners could collaborate in expanding the scale and scope of the business for the supplier.

Supermarkets also engage in contracting farms to grow produce under a particular brand name. Such contracts allow the supermarkets to place strict control on production inputs thereby allowing them to guarantee safety and quality to consumers. Contractual arrangements of this type strengthen retailer/supplier partnerships. The strength of these partnerships is sealed by consumer confidence in the brand name of the supermarket.

Interactions of stakeholder traders

The stakeholder trader comes in many forms. In the case of short supply chains, the supermarket supplier is either the trader or the farmer. The trader may, otherwise, be an importer/exporter outfit, a co-operative or an individual wholesaler. The main function of the stakeholder trader is to transport produce from the farm, distribute and market the produce and bring the produce closer to the consumer in situations where the grower or producer is not able to do so, because of either logistical or capacity constraints. The trader can offer different degrees of value to the value chain depending upon his input in that he could be a simple collector involved in buying and transporting produce to another trader in the town, or, he could add value to the produce by grading and repacking prior to delivery. In other cases, the stakeholder trader could be a government agency that facilitates trade of local produce.

Interactions of middlemen

The term, “middlemen”, has always had very negative connotations in that middlemen always suppress farm gate prices, derive extraordinary profit through imposing large mark-ups and take advantage of the farmer’s ignorance of prevailing market conditions. These practices are only prevalent if there is limited flow of information in the supply chain, either because of remoteness of farms, ignorance of farmers or manipulations of produce supply and demand figures by other stakeholders. Middlemen can, however, make a positive contribution to the value chain if all other stakeholders are educated and well informed, if there is no monopoly practice by retailers, if produce supplies are not restricted and if pricing mechanisms in the chain are not fixed or controlled by authorities.

Suppliers of equipment and transport

Suppliers of farm tools and equipment, and transportation companies that deliver produce from farms to retailers or to markets in refrigerated trucks add value to produce as well as a marginal cost for the services provided. Increased productivity resulting from the use of these service providers increases the competitive advantage of the producer.

Extension service providers

A key role player in horticultural supply chains is the agricultural extension officer who assists rural farmers in technical as well as in the social aspects of production. Farmers are usually highly dependent on extension officers for the modern production and marketing of their produce. Extension officers also provide assistance in informing the public of the availability of produce. State research and development officers and university researchers can also contribute to the development of rural farmers.

Pesticide companies, fertilizer companies and seed companies, provide extension services for training farmers in the proper application and use of their products. Farmers benefit from improved produce quality and reduced crop damage caused by pest and disease infestation. Commercial producers often benefit from engaging these free services.

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Suggested methods of instruction

Lecture using visuals or handouts and discussion.

Practical exercise

Practical exercise III.1: Visit to a fresh produce market.

Time frame

One hour for the lecture and discussion.
Two hours for the practical exercise.

Section III

Module 2 – Integration of small farmers into horticultural chains in Asia and the Pacific region*

Learning outcomes

The learner should:

- develop an appreciation of modalities for increasing the market access of small-scale farmers through horizontal and vertical coordination mechanisms.

Introduction

Income growth is rapidly increasing in Asia and the Pacific region. Urban growth is also increasing at a very rapid rate. New and diversified market opportunities are becoming available and information and communication systems have expanded with mobile phone communications and Internet services now accessible and affordable even in rural areas. High quality seeds, improved planting materials, tools and equipment are increasingly becoming available in the region.

At the same time, many small farmers in the region are becoming increasingly vulnerable to marginalization because of low productivity, poor quality outputs and limited market access. Averting this risk necessitates development of their skills and capacities in order to empower them to adopt new attitudes and approaches to farming and marketing. To meet this end, small farmers must also increasingly work collaboratively with each other either through networks or co-operative groupings in order to leverage on each other for more efficient production capacity. They must seek to identify niche opportunities for their fresh produce outputs, create and develop those opportunities that become available to them and then promote markets for their outputs.

This module discusses coordination mechanisms through which small farmers can enhance their competitiveness.

Horizontal collaboration in horticultural chains of Asia and the Pacific region

Clustering

Within the context of the competitive environment in which Asian farms currently operate, individual farmers must either compete and succeed or face marginalization. Every small farmer must, therefore, strive to have the constant edge over his neighbours.

The prospects of competitiveness work differently for a small farm than for a large farm with available resources. In order to achieve the competitive advantage usually associated with large farms, small farms

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* K. Chan

must collaborate with the other stakeholders in order to survive. Given their small size, the possibility of vertical collaboration with other small stakeholders is not advantageous. Greater benefit is derived through horizontal collaboration among small farmers.

Horizontal collaboration may involve small farms of similar sizes pooling together their resources and outputs and working collaboratively with service and technology providers (who are more interested in working with larger-scale farmers). Horizontal collaboration of small farms can be initiated either by small farmers themselves or through government programmes. Government programmes designed to promote horizontal collaboration could either reposition existing farms or direct the location of new farms, meanwhile bringing associated service providers into a designated geographical area through a *cluster initiative*.

Benefits of clustering

Geographical, cultural and institutional proximity of small farmers through clusters generates benefits that cannot be tapped from a distance. These benefits include:

- *Development of economies of scale* – Economies of scale can be generated particularly in the input sector (fertilizers, irrigation equipment), in logistics (consolidated trucking) and in marketing.
- *Increased access to information and improved information flows* – This is because of the geographical proximity of small farms, the associated service providers, input providers and technology providers (government research institutions with which small farmers will develop improved working relationships).
- *Improved adaptation of information and improved innovation* resulting from competition generated among small farmers that are in close proximity to each other.
- *Improved personal relationships among small farmers* – Geographical proximity also fosters the development of closer personal relationships among farmers and stakeholders (interconnected service providers and specialized suppliers), thereby reducing the cost of doing business that could result in the formation of trade associations, which will further strengthen the cohesion of the small farms.

Advantages of working in clusters

Advantages of working in clusters include:

- increased farm productivity;
- farms independently drive the direction and the pace of innovation; and
- development of new businesses in the cluster region as a result of competitiveness among farms. The cluster of competitive farms becomes more than the sum of its parts given that it introduces related service providers and leads to internal diversification.

Case of the organic carambola cluster in Serdang, Malaysia

Carambola (starfruit) cultivation appears to be predominant among Hakkas (Chinese descendants of South China) in the Hakka dominated village of Serdang, Malaysia. Early Hakkas in that village shared among themselves expertise in producing a larger, tastier carambola that is not found elsewhere in the country. The knowledge of bud wood selection and grafting, tree pruning, pollination and fruit bagging was not practised in other parts of the country. In the late 1970s, tastier carambola fruits produced by these Hakkas found markets in Hong Kong and Singapore. Growth in demand for the fruits in the Singapore market, resulted in more people (including non-Hakkas) coming into the village to work as growers, fruit baggers, collectors and transporters. The proximity of the village to the national agriculture research station MARDI, and the agriculture university UPM, may or may not have been planned, but had a powerful impact in driving technological development in carambola production. The village is now a major developed modern town, but some die-hard carambola traders still remain. The carambola growing regions have since spread to other Hakka towns and carambola remains a major fruit export of Malaysia.

One-village-one-product programme

The one-village-one-product (OVOP) programme is a regional development programme that was coined and popularized in the village community of Oita Prefecture in Japan. This programme originated from a number of regional community development activities that were initiated by the community people of Oita and facilitated by the local government. Since its inception in 1979, a number of similar effective programmes have been implemented in many developing countries of Southeast Asia.

The OVOP movement is based on three principles:

1. It encourages the production of commodities of local origin that can be globally competitive. The production processes immerse the regional and cultural flavours of a specific community in adding value to the product, making it competitive and unique, thereby allowing it to be marketed under a brand name.
2. Production is self-sustainable. Creative activities are based on local creative initiatives and decision-making, taking advantage of the resources of the community, its cultural uniqueness and originality and targeting the product to penetrate a niche market.
3. Human resources in the community are developed during the process of producing the product.

Based on the principles of the OVOP, local communities in any location that wish to emulate OVOP programmes must first identify their unique products, cultures and customs. They must assess their economic capacity to produce the product and work with each other to develop the supply chain that could further add value to that unique product. All associated and interrelated industries could collaborate to derive mutual benefit. Promotion and marketing may be facilitated by local or regional governments in situations where costs are high.

Basic requirements for the establishment of OVOP programmes in rural areas include transportation and communication infrastructure as well as seed capital to facilitate the procurement of equipment. More importantly, production technology must be offered at a level that is commensurate with existing knowledge and innovation within the community, in order as to maximize the use of skills and production capacities.

Application to the horticultural sector

Many of the outputs of the OVOP initiative in Southeast Asia are produced for export. Thailand and Malaysia have both linked their OVOP programmes to the tourism industry, promoting unique products alongside their unique traditions, fascinating culture and tourist attractions. In terms of fruits and vegetables, certain regions may possess distinctive varieties of produce having specific flavours that are unique to that specific area of the country. These fruits and vegetables may be developed through the OVOP programme. These OVOP outputs could also incorporate handicraft products and skills in the packaging of the produce.

Criteria for the success of OVOP programmes

OVOP programmes work best if local community participants assume responsibility for management of the supply chain and if distribution and marketing abilities are home grown. The intervention of the government in initiating such programmes should be as brief as possible in order to allow participants the opportunity to learn how to compete independently. Doing so would generate greater benefit for the community and enhance the sustainability of the programme.

Vertical collaboration in supply chains of Asia and the Pacific region

Vertical collaboration – The production of tropical produce in Southeast Asia and in many countries of the subcontinent follows the dry period or monsoon pattern. Tropical fruit trees, in general, bear one fruiting a year, often predictably during the period April to October (depending on the monsoon path and the rainy period). The production of non-tree fruit crops, soft fruit crops and vegetables is less predictable because of the fact that farmers follow their individual growing cycles. This lack of coherence in production greatly impacts upon the consistency of produce supplies and price stability.

In order to even out the regularity of production, improve the consistency of produce supplies and produce prices, it is advantageous for supermarket suppliers to collaborate with farmers through a production schedule (backward collaboration) and develop agreements that govern the supply of produce to the supermarkets (forward collaboration). Collaboration of this type is referred to as vertical collaboration of a simple supply chain. The idea is to regulate the supply of produce and to assure demand up and down the supply chain. An arrangement of this type helps smooth the flow of produce and stabilize prices.

Contract farming – One way in which the small farmer can enter into such a collaborative relationship with the supermarket supplier is through contract farming.

A contract is a forward agreement drawn up by a small farmer and a supplier that provides for the variety of crop grown, the timing of production, the acreage of production, the produce quality specifications, the price and the terms of payment. Other conditions stipulated by the contract would include the method of production, any practices or inputs that are prohibited or cultivation practices that must be followed. Inclusion of these criteria necessitates that the supplier has access to agricultural expertise or extension personnel for guidance, monitoring and advice on the control of practices. Farm extension personnel may be privately provided by the supplier or may work in collaboration with extension officers of agriculture departments.

A high level of organization is required in order to assure the success of contract farming. Simply managing large numbers of small farms over a wide area is inadequate. Transportation logistics, the availability of proper road and telecommunication infrastructure and services, managerial skills and operation management tools must be available.

Advantages of contract farming for small farmers

In addition to regulating fresh produce supplies, achieving more timely production and assuring better quality, contract farming provides small farmers the opportunity to access information, technology, assured marketing avenues and the opportunity to meet the safety standards required by supermarkets. The transfer of information, new planting skills and technology to the contract farmer adds value to the supply chain. The more knowledgeable the farmer, the greater is his success rate in producing a good crop.

Contract farming agreements facilitate timely delivery, help lower the risks of over production for the farmer, lower the costs of inputs and reduce wastage. Managing production with a large number of farms can result in operational efficiencies and economies of scale in transportation, handling and distribution to retail markets.

Management of the production and the supply of produce under contract farming with supermarkets is a forward collaboration in the supply chain which provides assurances to the supermarket and which translates to better marketing communication and trust, which is very important in business relationships.

Disadvantages of contract farming

The down side of contract farming arises when the supplier fails to provide extension assistance to the farmer, or fails to plan the production schedules and simply contracts an unrealistic forward price with the farmer. No commitments of the parties in these agreements would exist under such circumstances and this could result in breakage of the contract as a result of unforeseen circumstances.

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Suggested methods of instruction

Lecture using visuals or handouts and discussion.

Time frame

One hour.

Section III

Module 3 – Traditional and modern marketing channels for horticultural produce*

Learning outcome

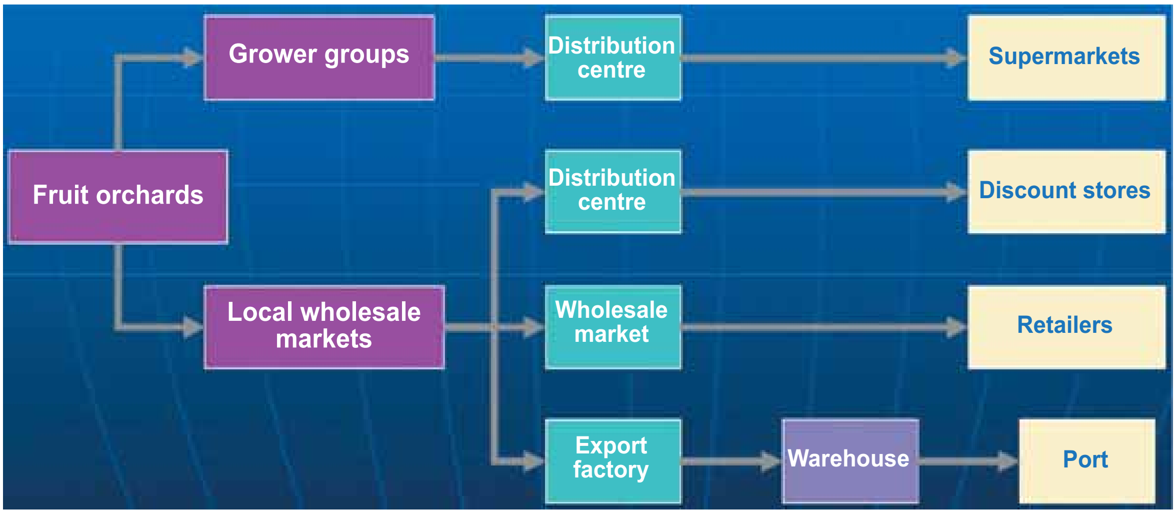
The learner should:

- develop an understanding of marketing channels and intermediaries involved in traditional and modern horticultural chains in Asia and the Pacific region.

Introduction

Horticultural produce is moved from production areas to the consumer via a number of different channels. Rapid growth of supermarkets has brought about changes in the marketing channels for horticultural produce in Asia and the Pacific region. Traditional and modern marketing channels for horticultural produce in the region are shown in Figure III.3.1.

Figure III.3.1. Marketing channels for tropical fruits



* J. Tangtermthong

This module briefly describes the traditional and modern marketing channels for fresh fruits and vegetables and the impact of modern trade on traditional chains in Asia and the Pacific region.

Traditional marketing channels

The traditional marketing chains for horticultural produce in Asia and the Pacific region are multi-layered and are characterized by an inadequacy of storage and packing systems, few linkages between suppliers, long lead times (up to 60 hours) from harvest to shelf and a lack of traceability and quality standards. In certain cases, high quality produce is supplied to upscale markets (e.g. supermarkets) or exporters whereas low quality or off-grade produce is marketed in domestic outlets such as wet markets.

Traditional supply chains are largely supply driven, with relatively little co-ordination. Horticultural crops are usually grown in rural areas or far from urban centres. Farmers generally access nearby rural consumers through informal transactions involving sales at the farm gate or village market centre.

Small rural markets are informal and are held periodically at an appropriate location in the village. Given their close proximity to production areas, produce is transported to market by head-load, bicycle or animal porterage. Direct transactions often take place between farmers and consumers.

Larger rural markets may be registered and supported by the local government. These may also be periodic and are likely to be outfitted with permanent stalls where traders sell to consumers and other traders. These markets draw farmers from long distances, so that produce is transported to market by minibuses and small trucks.

In the case of *urban markets*, produce is moved from rural areas through a chain of intermediaries, which may include assemblers, brokers, wholesalers and retailers. Assemblers and wholesalers supply produce to urban markets after purchasing it directly from farmers or from rural markets. The produce is transported either by minibus (for small quantities) or truck (for larger quantities). Commission brokers, acting on behalf of large and long-distance traders, play an important role in sourcing supplies, in organizing procurements into economical loads, and in marketing, especially given the wide-ranging agro-ecological zones within the region, the geographical distribution of production and the small sizes of farms. Terminal wholesale and semi-wholesale markets are located within or near major cities 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.

Fresh produce is marketed both formally and informally. Informal retailers include small-scale traders operating in traditional open-air retail markets or makeshift sheds and stands in high-density residential areas, on pavements in busy urban streets or in door-to-door hawking in residential areas. Although primarily involved in retailing, informal markets – also referred to as farmer's markets – may have a semi-wholesale function, particularly if farmer trading takes place in those markets. On the other hand, formal retail markets include supermarkets, convenience stores and small retail shops. Small retail shops – also known as urban self-serve stores, urban countertop stores, "corner" shops and roadside stands, depending on their particular operation – supply produce in the vicinity of the home of the consumer. These establishments generally procure their produce supplies from wholesale markets. Supermarket and convenience store chains are part of the modern marketing system.

Modern marketing channels

Modern marketing systems are more direct and straightforward than are traditional marketing systems. The marketing chains are well coordinated and are driven by consumer requirements. They are further characterized by centralized produce procurement systems, systematic storage and distribution systems, specialized suppliers who may be producer groups, contracted farmers or wholesalers, produce quality standards, and the use of advanced information/communication systems. Strategies employed include competitive pricing, the provision of consistent produce quality, procurement of large volumes of produce and proper logistics and distribution efficiency.

Supermarkets, store chains and export companies employ the strategies of modern marketing. Supermarkets are either foreign-owned, under the control of a foreign investor, or are owned by large domestic chains. Supermarkets and store chains may procure produce directly from farmers, individual large-scale farmers, farmer groups or cooperatives, private or government distribution centres, wholesale markets or independent suppliers. However, leading supermarket chains often bypass wholesale markets and rely primarily on a few brokers and on direct procurement arrangements with contracted commercial farmers and organized small-sized and medium-sized farmers.

Export marketing also follows the operation of modern supply chains. The channels used vary widely, but can be classified into roughly three categories according to the degree of vertical coordination:

- *Vertically-integrated exporters* – These 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.
- *Exporters who consolidate produce grown under contract* – These are exporters who obtain produce from contract farmers. In a majority of cases, large or medium-scale farmers supply exporters directly on a contract basis. In a few cases, a number of small farmers may also supply produce to exporters on a contract basis.
- *Exporters who consolidate produce procured by brokers* – In this case fresh produce is sourced through brokers, who in turn consolidate produce from farmers in spot market transactions, or alternatively through farmer groups to ensure the minimum standard of quality that will attract exporters or traders.

Impact of modern trade on traditional chains

Impact on wholesalers:

- reduced trading through auction;
- increased survival of large wholesale market;
- reduced number of suppliers;
- increased commodity specialization;
- new roles for suppliers; and
- shorter supply chains.

Impact on small retailers:

- increased use of packaging;
- increased responsiveness to consumer demand;
- competitive range of produce items;
- flexible time of store opening;
- creation of a wet market environment.

Impact on small farmers:

- increased contract farming;
- quality and safety production based on standards;
- increased use of private standards of quality and safety;
- improved production systems and quality of produce;
- more consumer information flow to farmers.

Conclusion

Traditional marketing has been affected by modern marketing systems. Some of the impacts include shrinkage of chains, more specialized suppliers of produce, more transactions through contracts, wider use of product quality and safety standards, and broader consumer base of quality produce. Participating in the modern marketing system is, however, very difficult for small farmers and suppliers with little capital and other resources.

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Suggested methods of instruction

Lecture using visuals or handouts and discussion.

Practical exercise

Practical exercise III.1: Visit to a fresh produce market.

Time frame

One hour for the lecture and discussion.
Two hours for the practical exercise.

SECTION IV

Horticultural produce quality

Section IV

Module 1 – Quality and safety in horticultural chains*

Learning outcomes

The learner should:

- develop an appreciation of the quality and safety attributes of horticultural produce;
- develop an understanding of the components of quality;
- develop an understanding of basic food safety programmes.

Introduction

Produce quality is a major determinant of consumer choice. Consumer preference for fruit or vegetable quality is a highly subjective judgement related to learned criteria. Quality criteria vary among different fruits and vegetables and may also depend on the perspective of the recipient in the supply chain. Food safety is important both from the health and safety perspective of the consumer. It is an important issue in international trade because barriers to free trade are gradually being removed. There are growing concerns that food safety could be used to limit international trade although this is prohibited by the United Nations World Trade Organization.

This module briefly describes the various aspects of fresh fruit and vegetable quality and introduces some food safety based quality assurance systems.

Fresh produce quality

Definition

Quality is defined by the International Organization for Standardization (ISO) as the totality of features and characteristics of a product that relate to its ability to satisfy stated or implied needs. It can also be defined as the combination of attributes, properties, or characteristics that give a commodity value in terms of its intended use (Kader and Rolle, 2004). Fresh produce is considered to be of good quality when it complies with the requirements desired by the client (customer or consumer). The quality required by a target client or market should be known as early as the production planning stage. Produce that is acceptable in local markets often differs from that desired by the buyer in other markets, both in terms of variety and attributes.

Quality attributes and stakeholder assessment

Quality means different things to different people. To the horticultural producer quality produce must be high yielding, of good appearance, easy to harvest, and resistant to pests, diseases and mechanical damage during harvesting and post-harvest handling. Wholesale and retail markets evaluate quality on

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the basis of appearance, firmness and shelf-life. Consumers judge the quality of horticultural produce on the basis of appearance, nutritional value, flavour and firmness at the time of initial purchase. Subsequent purchases depend upon the consumer's satisfaction in terms of the flavour (eating) quality of the edible portion of the produce. It should be noted that there is no typical consumer – people of different ethnicities and cultures may have different preferences, so a range of produce qualities may be required.

Evaluation of quality

Horticultural produce can be evaluated on the basis of a number of specific quality attributes. These include:

- *Appearance (visual)* – relates to the size, shape, colour, gloss and freedom from defects such as sprouting, shrivelling, bruising, insect or bacterial infection and decay. The uniformity of produce in terms of size, colour and ripeness is a key attribute noted by consumers.
- *Texture (feel)* – relates to the feel of the produce item in the hands or in the mouth. Textural attributes can be described in the context of firmness or hardness, crunchiness, crispness, tenderness, juiciness, mealiness and toughness, depending on the commodity. The textural quality of horticultural crops is not only important for their eating and cooking quality, but also for their ability to be transported through the horticultural chain.
- *Flavour (eating)* – relates to the taste and smell (aroma) of the produce. Taste is detected by the taste buds at the tip, sides and back of the tongue and aromas are detected by the olfactory epithelium in the upper part of the nasal cavity. Flavour attributes can be described in terms of sweetness, sourness (acidity), astringency (because of tannins), saltiness, bitterness, aroma (volatile compounds), off-flavours and off-odours. Most fruit and vegetables have sweet, sour and bitter tastes but little or no salty and umami tastes. Umami, which has recently been added to the other four tastes, is a savoury taste given by ingredients such as monosodium glutamate and other flavour enhancers and is significant in Japanese foods such as seaweed.
- *Nutritional* – relates to the vitamin, mineral, lipid, protein, carbohydrate, phytonutrient (antioxidant and flavonoid content) and dietary fibre content of fresh produce.
- *Safety* (see also below) – relates to factors that could make the consumption of fruits and vegetables unsafe. These factors include contaminants such as chemical residues and heavy metals, environmental pollutants, pesticide residues, physical hazards (e.g. glass, metal, etc.), pathogenic microorganisms, naturally occurring toxic plant products such as oxalates and nitrates, and toxigenic fungal products such as mycotoxins.

Objective measurements of quality which make use of instruments (e.g. colorimeter for colour, firmness tester for texture) are useful for routine quality control but cannot measure consumer preferences. The only sure way to determine what consumers think about fruit and vegetables is by using sensory testing and asking panellists to provide their opinions on the fresh produce item. Sensory evaluation is not, however, suitable for routine use and the best way of assuring quality is to find objective measurements that correlate to sensory attributes.

An additional dimension of quality, which has evolved in international markets, relates to credence attributes, i.e. attributes that depend on the method of production, regardless of whether the method of production has a visible or analysable impact on the produce. Examples of credence attributes desired by consumers include sustainable environmental profiles or fair trade conditions.

Food safety

Food safety is defined as the assurance that the food will not cause harm to the consumer when it is prepared and/or eaten according to its intended use. Measures and conditions are applied at various stages of the food chain (production, processing, storage and distribution) to ensure that the consumption of produce does not pose a risk to human health.

Risk is the probability of a hazard occurring.

A *hazard* is a biological, chemical or physical agent in the food with the potential to cause adverse effects on human health.

Importance of food safety programmes

Food safety programmes are primarily designed for consumer protection by providing consumers a guarantee on the safety attributes of the food to be consumed. These programmes also increase market access and market confidence. In recent years, food safety hazards and their associated risks have increased owing to changing demographics and consumption patterns, changes in distribution systems, global trade, new products and food types, new production and conservation technologies, the emergence of new food-borne pathogens, and immunological changes among population segments. In the case of fresh fruits and vegetables, critical safety issues include consumption of the produce in the fresh or pre-cooked form, market entry of new exotic produce items, increasing participation in global trade, and emergence of advanced techniques for the detection of contaminants.

Food safety hazards

Food safety hazards are biological, chemical or physical agents that can contaminate produce at any stage in the food chain, from production through harvesting, shipping, storage and distribution.

Biological hazards refer to pathogenic microorganisms that cause human illnesses directly when consumed together with the produce (infection) or by producing toxins or chemical substances harmful to humans in the produce before it is consumed (intoxication). In some cases, the microbial population may be insufficient to cause produce decay but may be enough to cause human infection or intoxication after the produce has been consumed. Thus, produce that is perfect in appearance is not guaranteed to be microbiologically safe. Pathogenic microorganisms can contaminate the produce through the soil, contaminated water, badly treated manure, sewage, air, poor worker hygiene, or contaminated surfaces of post-harvest facilities such as produce packages, transport and storage facilities.

Chemical hazards include natural substances (e.g. allergens, mycotoxins, alkaloids and enzyme inhibitors), chemical products (e.g. pesticides, water disinfectants), prohibited substances (e.g. some pesticides, methyl bromide) and toxic elements (e.g. lead, cadium, arsenic, zinc). Their adverse effects on human health are generally less dramatic and immediate than those caused by pathogenic microorganisms. However, there is growing concern for their possible long-term effects on human health, direct and indirect effects on the environment, flora and fauna, and effects on the health of rural workers. Chemical hazards can be introduced to fresh fruits and vegetables during production (e.g. phytosanitary products, fertilizers, antibiotics, growth regulators, etc.) and post-harvest handling (e.g. phytosanitary products, waxes, detergents, etc.).

Physical hazards include stones, glass particles, wood, hair, plastic, jewelry and metals which may be unintentionally introduced to the produce during production and post-harvest operations.

Food safety programmes

Food safety assurance programmes aim to protect the consumer by ensuring safe and wholesome produce and at the same time minimizing the negative impacts of production and post-harvest practices on the environment and workers' health that could threaten market credibility.

Prerequisite programmes. Good Agricultural Practice (GAP), Good Manufacturing Practice (GMP) and Good Hygiene Practice (GHP) are considered as prerequisite programmes for implementing safety assurance programmes such as Hazard Analysis and Critical Control Point (HACCP) and certification programmes (e.g. ISO 22000).

GAP includes practices that have to be followed during primary production and considers prior land use, adjacent land use, water quality, water use practices, soil fertility management, wildlife, pest and vermin control, worker hygiene and sanitary facilities, and harvesting, handling and storage practices as key areas for preventing food safety hazards.

GMP includes practices oriented to the prevention and control of hazards in the post-harvest chain. GMP is usually applied to the harvested produce and the areas of concern include worker hygiene, location of facilities (packing house, storage), sanitary operations, sanitary facilities and controls, equipment and utensils, and processes and controls.

GHP includes practices oriented to ensure the safety and aptitude of the use of fresh fruits and vegetables throughout the food chain, with emphasis on prevention and control of microbiological hazards. GHP is a horizontal component of GAP and GMP. Basic rules of GHP for the 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 procedures), maintenance and sanitation, personal hygiene and training of personnel. GHP forms an integral part of all food safety management systems including HACCP.

In practical terms, GAP, GMP and GHP have been incorporated into the codes of practice and protocols for certification under a generic concept of Good Agricultural Practices.

In practice, the implementation of food safety protocols involves cooperation between the official sector and private food producers along the entire horticultural chain. Contamination of fresh produce with food safety hazards (e.g. chemical pesticide residues, human pathogens, heavy metals) can occur at any step from production to retail. Food safety control can be achieved through the implementation of principles and guidelines of such frameworks as Good Agricultural Practice (GAP), Good Manufacturing Practice (GMP), Good Hygiene Practice (GHP), Hazard Analysis and Critical Control Points (HACCP), and ISO 22000. GAP, GMP and GHP are considered as prerequisite programmes for implementing safety assurance programmes such as HACCP and certification programmes.

HACCP – This is a systems approach that identifies potential sources of contamination in food production systems, establishes methods for detecting the occurrence of contamination, and clearly prescribes what corrective actions must be taken to prevent consumption of contaminated foods. It thus addresses biological, chemical and physical hazards through anticipation and prevention rather than through end-product inspection and testing. Its advantages include the following:

- it can be applied throughout the food chain;
- it makes more effective use of resources;
- it allows more savings to the food industry;
- it allows more timely response to food safety problems;
- it enhances the responsibility and degree of control throughout the food chain;
- it is compatible with the quality control systems; and
- it is flexible with regard to technological changes and procedures.

The seven basic principles of HACCP are: (1) assessment of hazards; (2) determination of critical control point (CCP) to control the identified hazards; (3) establishment of CCP limits; (4) establishment of CCP monitoring procedures; (5) corrective action when deviations from CCP limits occur; (6) HACCP verification; and (7) HACCP record keeping system.

ISO 22000 – This is a new food safety tool developed for agro-industry. It includes five component principles: (1) food safety management system including general requirements and documentation; (2) management responsibility encompassing management commitment and food safety policy, planning, communication and review; (3) management of resources that include personnel, facilities and work environment; (4) planning and realization of safe products that cover establishing prerequisite programmes, HACCP, verification and traceability system; and (5) validation, verification and improvement of the food management system.

Support programmes – Training of personnel involved in growing and harvesting is necessary to make them aware of GAP and their role and responsibility in protecting fresh produce from contamination or deterioration and to equip them with the necessary knowledge and skills to carry out agricultural activities and to handle fresh produce and agricultural inputs in a hygienic manner.

A traceability system is also necessary to trace back the place and agricultural inputs applied during primary production. Farm information must be linked with the next step in the food chain. Thus, proper documentation and record keeping must be employed. Records must be kept on seed quality, recommendations for pesticide application, weed control, irrigation, water quality analysis, soil analysis, pest control and cleaning and maintenance (of the establishment, machinery, equipment, utensils, etc.) activities.

Cost of food safety outbreaks

Food safety problems can cause enormous losses of opportunities. Exporters could lose market access, market credibility/reputation, competitiveness and foreign revenue. The industry as a whole could experience a number of complaints, product rejections, penalties and disputes, closure of businesses, and loss of investments and prestige. Governments will be required to deal with increased health care costs, loss of foreign revenue, and loss of credibility from consumers. Individuals would also bear the costs of medical care, missed work and wasted time.

Thus, there should be a shared responsibility to avoid food safety outbreaks. Governments must uphold the protection of the human population from food hazards that pose a threat to human health and raise the awareness of food chain actors and consumers on the importance of implementing safety assurance programmes. On the other hand, horticultural chain actors must ensure the supply of safe and wholesome produce and keep consumers informed of produce characteristics and associated costs and benefits.

Monitoring quality and safety in horticultural chains

Standards that integrate consideration of parameters such as appearance, shape, colour, bruising, blemishing, diameter, size, maturity, skin defects and residues are used for monitoring quality in horticultural supply chains and for ensuring that produce complies with buyers' requirements. Such 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 in terms of cleanliness, appearance, flavour, odour and maturity, definition of different classes or grades based on quality characteristics, acceptable produce size, presentation of the produce in terms of its 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).

Factors that could compromise quality and safety in horticultural chains

Quality loss results from factors that are both internal (physiological processes) and external (microbiological, chemical, environmental and mechanical) to harvested produce. Respiration and transpiration are physiological processes that can be greatly influenced by environmental conditions such as temperature, relative humidity, the composition of the gaseous environment and mechanical or physical damage to the produce. Microbial and chemical contamination can compromise the safety of horticultural produce greatly. Microbial contamination can be transmitted through improper cultural practices, by workers and through contact with soil and unclean surfaces.

Mechanisms for preventing and controlling quality loss and contamination in horticultural chains are the core of this training programme.

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Suggested method of instruction

Lecture using visuals and handouts and discussion.

Practical exercise

Practical exercise IV: Evaluating fresh produce quality.
(Observations on product quality and safety factors are also carried out in practical exercises II.1 and V which are linked to corresponding lectures).

Time frame

One hour for the lecture.
Three hours for the practical exercise.

Section IV

Module 2 – Technical dimensions of horticultural chain management to assure quality and safety*

Learning outcomes

The learner should:

- develop a perspective on the critical technical issues to be considered in horticultural chain management.

Introduction

The horticultural chain spans the continuum from the producer to the consumer and integrates a number of stakeholders. Horticultural chains vary in length and complexity. Every stakeholder in the chain (the producer, harvester, packing house employee, logistics service provider and so on) is an important and critical link in assuring the safety and quality of horticultural produce as it moves through the chain. Stakeholders must be properly trained and must be aware of the factors that could compromise the safety and quality of fresh produce both pre- and post-harvest. Weak links within the chain and poor logistical operations could compromise the competitiveness of horticultural produce, leading to risks to consumer health and serious economic losses.

Horticultural chain operations

Horticultural chain operations generally include those carried out during production, harvesting, before and during packing in the packing house, transport, storage, distribution and marketing. The complexity of operations and level of support systems (e.g. technology, infrastructure, and market information) vary in accordance with the type of producer (Figure IV.2.1), distance to market (e.g. distant markets require more complex operations than nearby markets), and the target market (e.g. export markets and supermarkets are more exacting in terms of quality and safety requirements, hence more complex operations are required for these than for wet markets).

Critical factors in horticultural chain management

Quality maintenance in horticultural chains hinges on temperature and relative humidity management, as well as protection from mechanical injury. The safety of produce must be assured by minimizing the risks of contamination from pre-harvest through post-harvest handling and retail.

Distance and time to market are critical considerations in horticultural chain management, given that fresh produce progressively deteriorates with increasing time between harvest and consumption. Direct

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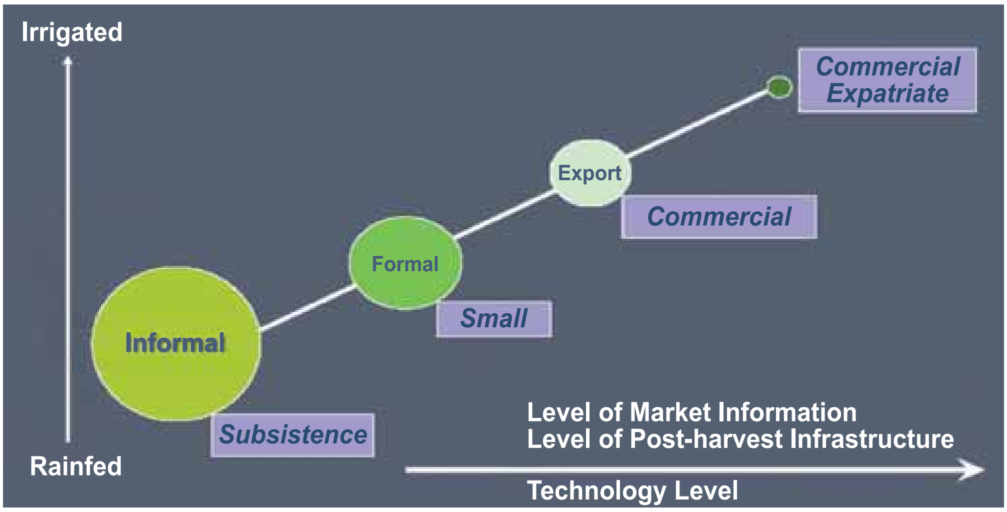
* R. Rolle

Figure IV.2.1. Four categories of producers in the countries of Asia and the Pacific region



and efficient marketing routes combined with appropriate logistical arrangements are required to assure the timeliness of delivery of fresh produce of high quality.

A well-equipped and hygienically maintained infrastructural base is a pivotal support element of the chain. The technological level of the equipment within that infrastructural support base must be appropriate to the needs of the target market and the length and complexity of the chain. For simple chains, for example in cases where the producer is within hours of the market, a simple infrastructural base consisting of packing and well-ventilated transportation facilities is adequate. For longer, more complex chains, packing houses, cooling systems and logistics infrastructure (refrigerated transportation, storage/warehousing and containerization, for example) supported by appropriate logistical operations are required to assure the maintenance of quality and timeliness of delivery to the target market.

Record keeping and documentation systems at every step of the chain allow the seamless flow of information up and down the chain and facilitate the tracking and tracing of produce between the producer and the market.

There is no substitute for good hygiene, proper handling, proper temperature management and efficiency within the chain if the quality and safety of fresh produce is to be guaranteed.

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Suggested method of instruction

Lecture using visuals and discussion.

Time frame

1 hour.

SECTION V

Factors impacting produce quality in horticultural chains at the production level

Section V

Module 1 – Crop variety and farm resources*

Learning outcomes

The learner should:

- understand the importance and principles of Good Agricultural Practice (GAP) in managing farm resources in horticultural crop production; and
- develop an appreciation of the importance of genetic material in meeting the produce quality requirements of markets and consumers.

Introduction

Fruits and vegetables are marketed primarily to generate income for the farmer and customers in the fruit and vegetable marketing chain. The profitability of fruit and vegetable marketing can be sustained only if customers and consumers make repeat purchases. Growers must, therefore, understand the nature and needs of the consumer, the market and customers within the supply chain.

In Module II.2, the customer and consumer were qualified. Each customer within the fresh produce supply chain has different requirements but, together with the growers, should be united in catering to meeting consumer requirements for the safety and quality of fresh produce. The traditional production-push mentality must be changed into a market-pull strategy. This is now critical as global supermarkets are increasingly influencing production at the local level, based on their standards of food safety and quality.

The supply chain begins with the selection of planting material and inputs and ends with the consumer. Each customer within the chain has specific views on remaining profitable. All customers within the chain are, however, interdependent and must rely on each other in order to perform optimally and maintain quality. Understanding and trust among all participants must exist in any successful supply chain.

At the production stage, several factors influence produce quality. In particular, some food safety problems have been traced to the mismanagement and misuse of farm resources (e.g. land, water, farm manure and manpower). Furthermore, a basic requisite of producing fruits and vegetables of desired market quality is the genetic material. In the past, crop breeding targeted yield increases whereas quality was based only on appearance and taste. Today, attention is increasingly focused on the nutritional and microbiological quality of fresh produce in order to respond to growing consumer demand for safe foods of high quality and to promote health and nutrition.

This module briefly describes the management of farm resources and the impact of genetic material on horticultural crop production.

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Farm resources

Good Agricultural Practice (GAP) is designed primarily to alleviate food safety problems. GAPs are increasingly being adopted in several countries in Asia and the Pacific region. Those who export fruits and vegetables to certain countries (e.g. Europe) must be certified compliant with the GAP system (e.g. GlobalGAP, which was previously EUREPGAP) of the importing country.

Some GAP considerations at farm level include: the history of land use; farm mapping including proximity to animal production and hazardous water or waste storage areas; worker hygiene and sanitary facilities; control of wildlife and pests; water quality and the application of water; management of soil fertility including the type, amount and frequency of fertilizer use; documentation of critical activities and processes, and training of workers on food safety.

Farm site

Deep fertile soils with adequate water availability are required for the production of horticultural crops. Topography is important in maximizing exposure to solar radiation, and in allowing adequate air flow. The general soil quality, land use and proximity of the farm to animals, manure or faecal matter and hazardous water storage areas are farm factors that contribute to the contamination of fresh produce with pathogenic microorganisms. Enteric (intestinal) pathogens such as *E. coli* and *Salmonella sp.* are common contaminants of vegetables where contaminated or polluted water is used for irrigation or where sewage sludge is used as fertilizer. Most fruits and vegetables contain nutrients that can support the growth of these pathogenic microbes. Once contaminated, the removal or destruction of pathogens on fresh produce is very difficult. Prevention of microbial contamination pre-harvest and at all steps of the horticultural chain is strongly advised over treatments to eliminate contamination.

Farm manure

Animal manure as organic fertilizer (biofertilizer) or other waste products are often used to promote plant growth and soil fertility. However, these materials can contaminate fresh produce with food-borne pathogens. Biofertilizers should, therefore, be treated (i.e. composted, dried, heated or decontaminated in some other way) prior to application in the field. Animal manure must not be spread between crops if there is the likelihood of direct contamination.

Agricultural water

Water used during crop production, if not of appropriate quality, could introduce water-borne pathogens into the horticultural chain. Water used for irrigation is, therefore, an important control point in fruit and vegetable supply chains.

Water sources must be frequently tested for microbial contamination. In situations where water quality cannot be controlled (e.g. water obtained from rivers, lakes and dams), producers should use other good management practices to minimize the risk of contamination. This can be done by minimizing contact between the edible portion of the plant and water. Many small farmers are reliant on natural rainfall and are therefore not affected by this requirement.

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 strategy implemented.

Worker training

Human resources employed on the farm can play a role in the spread of pathogenic microorganisms to fresh fruit and vegetables. All workers must be trained in food safety risks and good hygiene practices. Sanitation facilities (e.g. wash areas for workers and farm implements) must also be available on farm.

Genetic material

The quality and potential shelf life of fruits and vegetables are partly under genetic control and can be manipulated by breeding. Breeding for increased shelf life, desired shipping quality and high nutritional value is particularly needed in developing countries with hot and humid climates where refrigerated facilities are lacking, post-harvest losses are high, and malnutrition is rampant.

Greater efforts must, therefore, be made to develop fruit and vegetable varieties with better keeping qualities, desired shipping and processing attributes, and high levels of nutrients, in addition to developing tropical (high temperature-resistant) varieties of otherwise temperate or semi-temperate crops such as apple, strawberry, carrot, potato and Brassica vegetables (e.g. cabbages, cauliflower, broccoli). Conventional and novel breeding techniques have been used to produce papayas or tomatoes of high firmness, slow ripening rates and long shelf life as well as leafy vegetables such as lettuce of a high carotenoid (β-carotene and lutein) content. Other nutrients with therapeutic or pharmaceutical use (nutraceuticals) have also been targeted in breeding programmes for fruits and vegetables. However, the possibility of accidentally lowering beneficial non-target components while enhancing target phytochemicals has become a growing concern.

Often it is best to breed crops from local germplasm or under local conditions and constantly look for mutations. Many tropical fruits are derived from seeds, thus there is a large variation of tree and fruit quality, which can be used to select the best seedlings for continuing evaluation and breeding. Some important fruit attributes include: attractive appearance, resistance to diseases and pests, desired taste and flavour, extended storage and shelf life. Important tree attributes on the other hand include: small tree size and amenability to vegetative propagation to achieve uniformity of tree and fruit characteristics. Some of these attributes can be controlled by using appropriate rootstocks. However, there are very few examples of size controlling rootstocks in tropical and subtropical fruit trees. Optimization of uniform annual yields and reduction of variations in fruit quality (e.g. truss tomatoes that ripen sequentially and uniformly along the truss) are also areas that need further investigation.

For some fruit and vegetables, a wide range of genetic materials is available commercially and for new varieties, royalty payments are common. Using these new varieties as a value-added production activity could better position growers in serving market needs.

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Suggested methods of instruction

Lecture using handouts or visuals and discussion.

Practical exercise

Practical exercise III.2: Visit to an orchard.

Time frame

20 minutes for the lecture.
One day for the practical.

Section V

Module 2 – Environmental factors*

Learning outcomes

The learner should:

- develop an appreciation of the influence of environmental factors during production on the quality of fresh horticultural produce.

Introduction

Produce quality is affected by the plant environment, i.e. the soil environment and the aerial environment during growth and development. Soil factors can be manipulated by appropriate cultural practices such as by the application of fertilizer and organic matter (this will be covered in Module 3). Control of the aerial environment, i.e. light, temperature, humidity, and rainfall is, however, difficult unless highly controlled protected cultivation is used. Understanding the effects of these factors on produce quality will enable appropriate adjustments in production.

Light

Light is vital to plant life. It is used in photosynthesis to produce sugars, allowing plants to grow. Sugars are carbon sources that contribute to plant form (cell walls) and function (substrate for metabolism). They flow from the leaves to different parts of plants including fruit, stem and root. Sugars are converted to starch, contributing to food reserves and dry matter. Dry matter is important for taste and flavour, a market requirement that differs from country to country. Taste and flavour are key attributes for determining the repurchasing behaviour of consumers.

Light incidence

Incident radiation varies even within a tree. Fruit in full sunlight may have different quality and post-harvest attributes from those in shaded parts of the tree, leading to variations in fruit quality. Flesh of exposed fruit may reach temperatures of more than 40°C. This can have an impact on the transpiration rate, hence mineral uptake, and respiration rate. Citrus fruits in full sunlight generally have lower average weights, thinner skin, lower juice content, lower acidity and higher soluble solids or dry matter. Pineapples in shade are more acidic and less sweet than fruit in full sunlight. In mustard greens, low light stress (shading) before harvest can result in more rapid yellowing and wilting and lower sugar, organic acids and chlorophyll contents.

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Managing light

Pruning to remove unwanted branches improves light penetration and distribution thereby facilitating an increase in carbohydrate production (photosynthesis) and distribution, which is essential for dry matter accumulation.

Temperature

Temperature extremes limit plantings because of frosts or chilling stress for tropical crops, and heat stress for temperate crops. High or low growing temperatures can also affect the quality of fresh produce. Pineapples grown in areas with low night temperatures may, for example, develop internal browning (black heart). High temperature during fruit maturation and ripening limits the synthesis of lycopene (red colour) in tomatoes and β-carotene (yellow or yellow orange colour) in some citrus species such as mandarins. In cabbage, puffiness (reduced firmness or solidity) is induced by high temperature. Mangoes that are ripened on trees under high temperature conditions are of abnormal texture.

Relative humidity (RH)

High RH reduces transpiration (water loss) and consequently the mineral uptake of the plant, which in turn affects produce quality. A dense canopy provides a humid microclimate (i.e. within the tree canopy) that is ideal for some pathogens that appear post-harvest, such as *Botrytis.* In mangoes, high RH within the tree canopy has been found to favour infection by the anthracnose pathogen *Colletotricum gloeosporioisdes*, a latent infection the symptoms of which appear post-harvest when the fruit ripens. Opening up the canopy to allow air flow minimizes microbial infection. This can be done by selective pruning of branches.

Rainfall

Rainfall has significant influence on produce quality especially in rainfed areas. Too much rain prior to the harvest of many vegetables causes brittleness of leaves and susceptibility to harvest and post-harvest handling damage, creating favourable conditions for microbial infection. Lettuce harvested during a period of rain is of poor shipping quality and is susceptible to high levels of losses. Produce that has been stressed by too much or too little rainfall is particularly susceptible to post-harvest diseases. The impact of water stress on quality varies in accordance with the produce item. Outbreaks of food-borne illnesses have been traced to contamination of produce because of adhering soil particles during rainy periods. Problems of this type can be prevented by proper mulching and sanitary washing in the packing house.

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Suggested methods of instruction

Lecture using handouts or visuals and discussion.

Practical exercise

Practical exercise III.2: Visit to an orchard.

Time frame

20 minutes for the lecture.
One day for the practical.

Section V

Module 3 – Cultural practices*

Learning outcomes

The learner should:

- understand the impact of cultural practices on quality in horticultural chains.

Introduction

Crop management practices have a tremendous impact on the safety and quality of fresh produce. In general, the use of appropriate cultural practices (i.e. the selection of planting material, mineral nutrition, irrigation, and chemical sprays) ensures produce outputs that are safe and of high quality. This module describes some impacts of cultural factors on fresh fruit and vegetable quality.

Selection of planting materials

In order to obtain produce of optimal quality that conforms to consumer and market demand, the producer must select planting material that is well suited to the soil and climate on the farm. Seeds must be sourced from certified suppliers in order to ensure optimum yields and resistance to pests and disease. When purchasing nursery seedlings or trees, it is essential that the nursery is certified to a local standard or is part of a national plant improvement programme. If growers do not buy seed from registered suppliers, they risk buying infected or poor quality seeds.

Mineral nutrition

A balance of macro- and micro-elements is required for optimum plant growth and for quality produce. Deficiencies of both elements will reduce plant performance and compromise produce quality at harvest and during the post-harvest life.

Excesses or deficiencies in soil nutrients have varied effects on produce quality. Excess nitrogen could result in poor keeping quality and increase susceptibility to physiological disorders. High levels of nitrogen induce cell expansion and hence rapid post-harvest softening. In some Brassica vegetables, susceptibility to bacterial soft rot increases with the application of nitrogen as foliar feed, hence soil application is recommended. Low potassium in tomatoes causes uneven colouration, reducing eye appeal.

Calcium and boron deficiencies have a significant impact on fresh produce quality. Calcium deficiencies have a major impact on post-harvest quality, given that calcium has a pivotal role in maintaining cell membranes and cell wall integrity. Calcium concentrations in fruit decline as they progress through

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development. In some fruits, xylem in the peduncle becomes dysfunctional several weeks prior to harvest, so no further calcium uptake is possible.

Calcium deficiency causes pit formation, internal and external browning and tissue breakdown. Produce-specific symptoms are as follows:

- alfalfa – greening;
- apple – bitter pit; cracking; lenticel blotch; internal browning; senescent breakdown; water core; chilling injury;
- avocado – end spot; malformation; chilling injury;
- beans – hypocotyl necrosis;
- carrots – cracking; cavity spot;
- celery – blackheart;
- cherries – fruit cracking;
- kiwifruit – pitting;
- lettuce, cabbage and strawberry – tipburn;
- mango – softnose;
- pears – corkspot; and
- tomato and capsicum – blossom end rot.

Boron deficiency produces symptoms that are similar to those of calcium deficiency. Boron deficiency in Brassica plants induces hollow stem. Calcium and/or boron sprays can minimize deficiency disorders.

The use of organic fertilizers and the practice of organic farming are growing in popularity owing to consumer concerns about food safety. The application of farm manure (e.g. chicken dung, and cow manure) is a common practice in fruit and vegetable production. Farm manure, however, poses a food safety hazard and must be properly treated prior to application.

The application of excessive amounts of fertilizers can lead to ground water contamination with nitrate, which is a major problem in some places.

Irrigation

The supply of adequate supplies of water to growing plants generally enhances the quality and storability of fresh produce. In order to reduce food safety risks, the use of irrigation water from farm ponds used by livestock is not encouraged, as this increases the risk of pathogen contamination. Overuse of ground water leads to salination and some consumers are opposed to this.

Chemical sprays

Spraying with pesticides as a control measure for insect pests and diseases is a common practice. The potential problem of pesticide residues can be minimized by observing proper pesticide application practices and by employing other cultural practices such as fruit wrapping of mangoes and bananas in the field.

Farmers must use approved pesticides and must adhere to the use of correct spray dosages and withholding periods (minimum interval between application and harvesting). Failure to consider the withholding period can lead to rejection of entire shipments if detectable chemical residues are found.

The use of growth regulator sprays is also a common practice in many horticultural production systems. Chemicals that regulate ethylene biosynthesis and/or action are commercially applied to control ripening and senescence and to enhance harvest efficiency and optimize market opportunities.

Ethephon (Ethrel is the trade name) is an ethylene-releasing chemical that facilitates the even ripening of pineapple and processing tomatoes when used as a pre-harvest spray. ReTain™, a plant growth regulator, inhibits ethylene synthesis on apples and kiwifruit when sprayed four weeks before commercial harvest.

In recent times, the use of 1-methylcyclopropene (1-MCP) or "SmartFreshSM," an inhibitor of ethylene action, has grown in popularity. Pre-harvest and post-harvest treatments can inhibit ripening and senescence of fresh fruits and vegetables but responses differ in accordance with variety, maturity and growing season. SmartFreshSM has been cleared for use in:

- climacteric fruit – apple, apricot, avocado, banana, blueberry (highbush), Chinese jujube, custard apple, fig, kiwifruit, litchi, mango, melon, mountain papaya, peach, pear (Asian), pear (European), persimmon, plum, tomato;
- non-climacteric fruit – cherry, grapefruit, lime, orange, pepper, pineapple, strawberry, watermelon; and
- vegetables – broccoli, carrot, Chinese cabbage, Chinese mustard, choysum, chrysanthemum, coriander, lettuce, mibuna, mizuma, pakchoy, parsely, potato, tatsoi.

Conclusions

Horticultural crops must be produced to meet and extend market needs and desires. Production factors are important since they determine the quality and safety of fresh produce. High quality cultivars must be selected and must be grown in the appropriate location with proper management. Understanding interactions in supply chains is also essential. A challenge to scientists and extension workers is to optimize the pre-harvest conditions to ensure post-harvest quality. A number of enabling technologies are available to achieve this, but research and development is required to provide adequate and innovative production guidelines for growers. Meeting consumer needs for food quality, safety and nutrition is the key to the sustained market growth and prosperity of growers.

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Suggested methods of instruction

Lecture using handouts or visuals and discussion.

Practical exercise

Practical exercise III.2: Visit to an orchard.

Time frame

20 minutes for the lecture.
One day for the practical.

SECTION VI

Factors impacting produce quality throughout the horticultural chain

Section VI

Module 1 – Physiological factors*

Learning outcomes

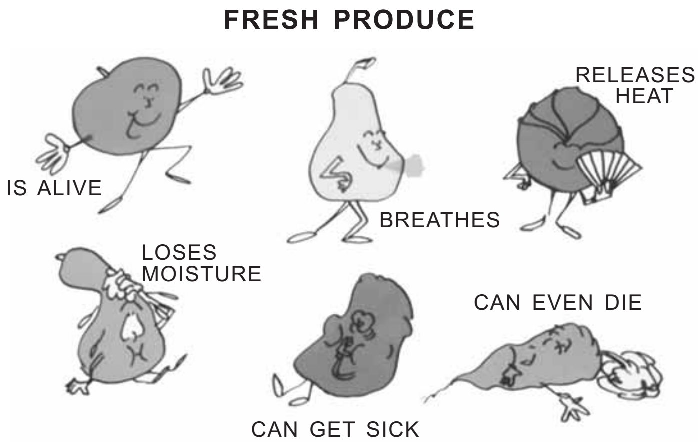
The learner should:

- understand the physiological factors that have an impact on the quality of horticultural produce.

Introduction

Harvested fruit and vegetables are living entities and continue to perform the metabolic functions that were present when they were attached to the plant (Figure VI.1.1).

Figure VI.1.1. Characteristics of living plant tissue after harvest



Source: Kader and Rolle, 2004.

Harvested fruits and vegetables cannot, however, undertake photosynthesis (e.g. green leafy vegetables) or receive photosynthetic products (e.g. storage organs such as fruit and root vegetables) and are cut off from supplies of water and mineral nutrients. They must, therefore, live on stored reserves. Depletion of stored reserves through respiration (breakdown of stored carbohydrates) and transpiration (loss of stored water in vapour form) lead to deterioration in quality. A basic understanding of post-harvest physiological processes and mechanisms for their control is critical for effective quality maintenance throughout the horticultural chain.

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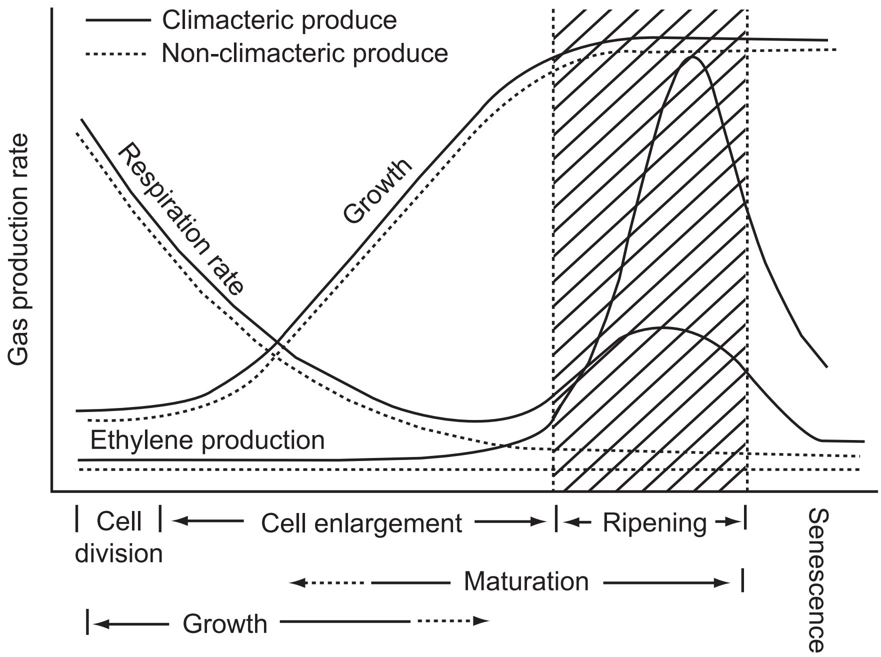
Physiological development of fruits and vegetables

The life cycle of fruits and vegetables can be divided into three stages following initiation or germination, namely growth, maturation and senescence (Figure VI.1.2). No clear distinction exists between these stages, given that each stage progressively merges into the subsequent stage.

- *Growth* involves cell division and cell enlargement that determines the final size of produce.
- *Maturation* usually begins before growth ceases. Growth and maturation are generally referred to as the development phase.
- *Senescence* is the period when synthetic biochemical processes give way to degradative processes, leading to death of tissue.

Fruit ripening begins during the later stages of maturation but before senescence begins. It is a result of complex processes that lead to the development of typical colour (pigment changes), softening (carbohydrate changes including pectins), and flavour (changes in carbohydrates, organic acids, phenolics and volatile compounds). Ripening and senescence may proceed either on the plant or after harvest. Fruits and vegetables can be classified as being either climacteric or non-climacteric depending on their patterns of respiration and ethylene production.

Figure VI.1.2. Growth, respiration and ethylene production patterns of fruit and vegetables



Source: KMUTT, 2007.

Respiration

Harvested produce is alive, which means that it undergoes respiration. Respiration involves the breakdown of carbohydrates and results in the production of carbon dioxide, water and heat (Figure VI.1.3). Respiration occurs both in the pre- and post-harvest phases.

Figure VI.1.3. Aerobic respiration

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

In the post-harvest phase, respiration is supported by carbohydrate reserves of produce and leads to a net loss in dry weight or negative growth. The more rapid the respiration rate, the faster will the produce consume its carbohydrate reserves, the greater the heat produced and the shorter the post-harvest life.

Carbohydrate breakdown during respiration leads to losses in food value, flavour, texture and weight, and thus to overall quality loss. Loss in weight, in particular, results in economic loss to the producer. Every effort must therefore be made to slow the respiration rate of produce in order to minimize quality losses, extend shelf life and minimize economic losses to the producer.

Climacteric versus non-climacteric respiration patterns

Fruits and vegetables can exhibit either climacteric or non-climacteric respiration patterns.

- *Climacteric produce* – exhibits an increase in respiration during ripening (Figure VI.1.2). Climacteric fruit have the capacity to ripen normally after harvest when harvested in the mature green state.
- *Non-climacteric produce* – does not exhibit a respiratory upsurge during ripening or senescence. Non-climacteric fruit, such as citrus, longan and rambutan, are generally harvested at the ripe stage and post-harvest operations of these produce items are generally directed toward improving their appearance, through, for example, peel degreening (in citrus) and control of pericarp browning (in longan and rambutan).

Table VI.1.1 shows examples of climacteric and non-climacteric produce and their relative rates of respiration.

Table VI.1.1. Climacteric and non-climacteric fruit and vegetables and relative respiration rate

Rate	Respiration at 5°C (mg $CO_2 kg^{-1} h^{-1}$)	Climacteric produce	Non-climacteric produce
Very low	<5		Dates, dried fruit and vegetables, nuts
Low	5 to 10	Apple, honeydew melon, kiwifruit, papaya, persimmon, watermelon	Beet, celery, citrus, garlic, grape, onion, pineapple, potato
Moderate	10 to 20	Apricot, banana, blueberry, cantaloupe, fig, mango, nectarine, peach, pear, plum, tomato	Cabbage, celery, cherry, cucumber, olive
High	20 to 40	Avocado, blackberry, raspberry	Carrot (with tops), cauliflower, leeks, lettuce (leaf), lima bean, radish (with tops)
Very high	40 to 60		Artichoke, bean sprouts, broccoli, Brussel sprouts, cut flowers, endive, green onions, okra, snap bean, watercress
Extremely high	>60		Asparagus, mushroom, parsley, peas, spinach, sweet corn

Source: KMUTT, 2007.

Factors that influence the respiration rate of fresh produce

The respiration rate of fresh produce is affected by temperature, atmospheric gases and physical stress.

- *Temperature* – Temperature has a significant influence on the respiration rate of produce and the greatest impact on quality deterioration after harvest. The higher the storage temperature, the greater is the rate of respiration. The rate of deterioration increases two to three-fold with every 10°C increase in temperature (Table VI.1.2).

Table VI.1.2. Effect of temperature on deterioration rate of a non-chilling-sensitive commodity

Temperature °C	Assumed Q_{10}*	Relative rate of deterioration	Relative post-harvest life	Loss per day (%)
0	--	1.0	100	1
10	3.0	3.0	33	3
20	2.5	7.5	13	8
30	2.0	15.0	7	14
40	1.5	22.5	4	25

Source: Kader and Rolle, 2004.

$$*Q_{10} = \frac{\text{Rate of deterioration at temperature T + 10°C}}{\text{Rate of deterioration at temperature T}}$$

Respiration rates can be slowed by storing produce in low temperature conditions that do not cause physiological damage to the produce. Temperature management is pivotal to controlling respiration and to maintaining quality.

- *Atmospheric composition* – Adequate levels of O_2 are required to support the process of aerobic respiration in harvested produce. The exact level of O_2 required to reduce respiration while allowing aerobic respiration varies in accordance with the type of produce. An O_2 level of between 2 to 3 percent generally produces a beneficial reduction in respiration and other metabolic reactions. Lower O_2 levels could lead to anaerobic respiration and off-flavour development in produce as a result of alcohol formation. Post-harvest handling treatments such as waxing, coating, film wrapping and controlled atmosphere can be used to regulate the availability of O_2 to harvested produce.

  Respiration is also stimulated by the presence of ethylene in the environment of fresh produce. Ethylene enhances the onset of the respiratory climacteric, ripening of climacteric fruit and senescence of non-climacteric plant tissues.

- *Physical stress* – Mild physical stress can perturb respiration rates of produce. Bruising can result in substantial increase in the respiration rate. Avoidance of mechanical injury through proper packaging and handling is critical to assuring produce quality.

Transpiration or water loss

Fresh produce contains 70 to 95 percent water and loses water constantly to the environment in the form of water vapour. The rate of water loss varies in accordance with the epidermal or skin characteristics of the produce (e.g. tissue structure, dimension and number of natural openings such as stomata, lenticels and cuticular breaks, nature of the cuticle, presence of appendages such as hairs and trichomes), exposed surface area of produce, and vapour pressure deficit (VPD) between the produce and its environment.

VPD is the driving force for water loss from produce. It is inversely related to the relative humidity (RH) of the environment. Under low RH, VPD is high and water is rapidly lost. The rate of water loss increases exponentially with increasing temperature and linearly with decreasing RH. Water loss is also enhanced by physical injury.

Water loss in harvested produce cannot be replaced, thus resulting in wilting, shrivelling, loss of firmness, crispiness, succulence and overall loss of freshness. These undesirable changes in appearance, texture and flavour, coupled with weight loss, greatly reduce the economic value of produce. Wilted leafy vegetables may, for example, require excessive trimming to make them marketable. In addition, water loss results in the loss of water soluble nutrients particularly vitamin C. It can also increase ethylene production which further accelerates the rate of quality deterioration.

Water loss can be controlled through temperature management, packaging and the adjustment of storage RH. Care must, however, be taken to avoid condensation of moisture on the surface of produce as this could contribute to decay development. Proper handling is also important to minimize physical injury.

Ethylene production

Ethylene (C_2H_4) is the only natural gaseous plant growth hormone that regulates many aspects of growth, development and senescence at less than 0.1 ppm. Low levels of ethylene production can be detected in most plant tissues. Ethylene, however, generally acts at genetically predetermined stages in the development of plant organs. Ethylene is also an environmental pollutant, being produced by internal combustion engines, propane powered equipment, cigarette smoke and rubber materials exposed to ultraviolet light.

The rate of ethylene production by fresh produce is largely dependent on whether the produce is climacteric or non-climacteric. Table VI.1.3 provides examples of produce and their relative rates of ethylene production. Knowledge of these relative rates of ethylene production is important in storage and transport applications, particularly in the case of mixed loads in which high-ethylene producing produce must not be mixed with ethylene-sensitive produce.

Table VI.1.3. Climacteric and non-climacteric fruit and vegetables and relative ethylene production rate

Rate	Ethylene production at 20°C (ml $C_2H_4kg^{-1}h^{-1}$)	Climacteric produce	Non-climacteric produce
Very low	<0.1		Artichoke, asparagus, cauliflower, cherry, citrus, grape, jujube, strawberry, pomegranate, leafy vegetables, root vegetables, potato, most cut flowers
Low	0.1 to 1.0	Blackberry, blueberry, casaba melon, persimmon, raspberry	Cranberry, cucumber, eggplant, litchi, okra, olive, pepper, pineapple, pumpkin, tamarillo, watermelon
Moderate	1 to 10	Banana, fig, guava, honeydew melon, mango, plantain, tomato	
High	10 to 100	Apple, apricot, avocado, cantaloupe, feijoa, kiwifruit, nectarine, papaya, peach, pear, plum	
Very high	>100	Cherimoya, passion fruit, sapote	

Source: KMUTT, 2007.

Ethylene production generally increases with maturity at harvest (particularly in the case of climacteric produce), physical injury, disease infection, temperature stress (high or low temperatures), and environmental stress (e.g. shortages of water).

Ethylene has both beneficial and harmful effects on produce quality. It enhances quality by promoting desirable colour development and by stimulating the ripening of climacteric fruit. It, however, accelerates unwanted ripening and softening of fruits, senescence and loss of green colour in leafy, floral and immature fruits and vegetables, russet spotting on lettuce and abscission of leaves.

Because of these diverse effects of ethylene, controlling its action is of great economic importance to producers, wholesalers, retailers and consumers of fruit and vegetables. The deleterious effects of ethylene can be overcome through low temperature storage, controlled or modified atmosphere storage, ventilation of ripening rooms, segregation of ethylene producing commodities from ethylene sensitive ones, the use of ethylene absorbers such as potassium permanganate ($KMnO_4$) in storage rooms and produce packs, and the application of ethylene inhibitor, such as 1-methylcyclopropene, which has been approved for use on selected fruit and vegetables.

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Suggested methods of instruction

Lecture using handouts or visuals and discussion.

Time frame

One hour.

Section VI

Module 2 – Microbiological factors affecting quality*

Learning outcomes

The learner should:

- understand the different kinds of microorganisms and the causes and mechanisms by which plant diseases are spread;
- understand the different alternatives for controlling post-harvest diseases; and
- develop an appreciation of the nature, importance and control of microorganisms that are harmful to human health.

Introduction

Microorganisms are of serious concern in horticultural chains. Microbial contamination can render fresh produce unsafe for human consumption and can lead to serious economic losses as a result of partial or complete loss of fresh produce quality and edibility. Protection against harmful microorganisms and their interactions with fresh produce are major targets of quality and safety assurance programmes. Understanding the nature and control of microbiological factors is the key to effective planning and management of quality and safety assurance programmes for fresh fruits and vegetables.

This module describes the different groups of microorganisms, their impact on fresh produce quality and safety, and control measures that can be applied in horticultural chains to avoid microbial contamination of fresh produce.

Microorganisms

Microorganisms are small organisms that can be observed only through a microscope. They include fungi, bacteria, viruses, viroids, nematodes, mycoplasma and protozoa. They can be found everywhere in the environment.

Beneficial and harmful microorganisms

Microorganisms are either harmful or beneficial.

Harmful microorganisms, also collectively termed pathogens, can cause crop failure or reduction in the yield and quality of harvest, partial or total loss of the quality of harvested fresh produce (spoilage microorganisms), and human illnesses (pathogenic microorganisms). Harmful microorganisms are effectively plant or human pathogens.

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* P. Jitareerat

Plant pathogens cause diseases to standing crops in the field with or without symptoms (visible manifestations in plants in response to microbial action, such as stunted growth, leaf spotting or curling) and to harvested produce with symptoms (e.g. rotting, spotting) that reduce produce quality and marketability. These plant diseases are also referred to as infectious diseases (i.e. diseases caused by biotic factors or living organisms that are transmissible) to differentiate them from non-infectious diseases (i.e. diseases caused by abiotic or non-living factors such as extreme environmental conditions that are not transmissible).

Human pathogens (pathogenic microorganisms such as *Escherichia coli* and *Salmonella*) can pose a food safety risk to human health.

Both plant and human pathogens can contaminate fresh produce through contact with the soil and other debris and through poor production and handling practices such as occurs through the use of untreated manure or contaminated irrigation water during production or during unsanitary handling practices.

Beneficial microorganisms provide for agricultural needs (e.g. nitrogen-fixing bacteria, microbial-aided composting, and microbial antagonists or microorganisms that antagonize harmful microorganisms), industry needs (e.g. microorganisms used in the production of enzymes, antibiotics and glycerol), and human needs (e.g. microorganisms used in the production of bread, cheese, wine, beer, sauerkraut and soy sauce).

Post-harvest diseases

Nature and importance

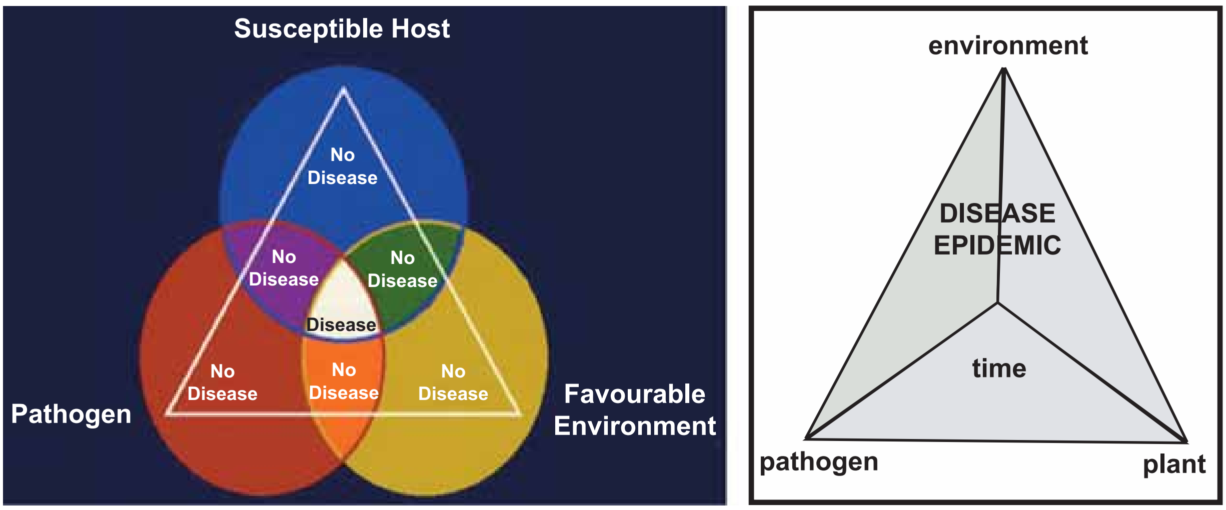
Post-harvest diseases are mainly fungal and bacterial infections. Fruits are more frequently affected by fungal pathogens because of their low levels of acidity (low pH) whereas vegetables are susceptible to attack by bacterial pathogens because of the fact that they are neither acidic nor basic, but are at a neutral pH. Post-harvest diseases result in losses in quantity (e.g. weight loss, trimming loss, or complete loss of the commodity), quality (e.g. visual quality loss, nutritional loss), economic value (e.g. reduced price), and safety (e.g. aflatoxins produced by *Aspergillus* species that at the same time can cause spoilage). Control of post-harvest diseases contributes to preservation of fresh produce quality.

Disease development

Diseases develop only when there is a virulent and aggressive pathogen, susceptible host and a favourable environment – the three components of the disease triangle – and given appropriate timing, can result in an epidemic (Figure VI.2.1).

Figure VI.2.1. Conditions for the development of plant diseases and epidemics

A. Disease triangle **B. Disease pyramid**



Source: KMUTT, 2007.

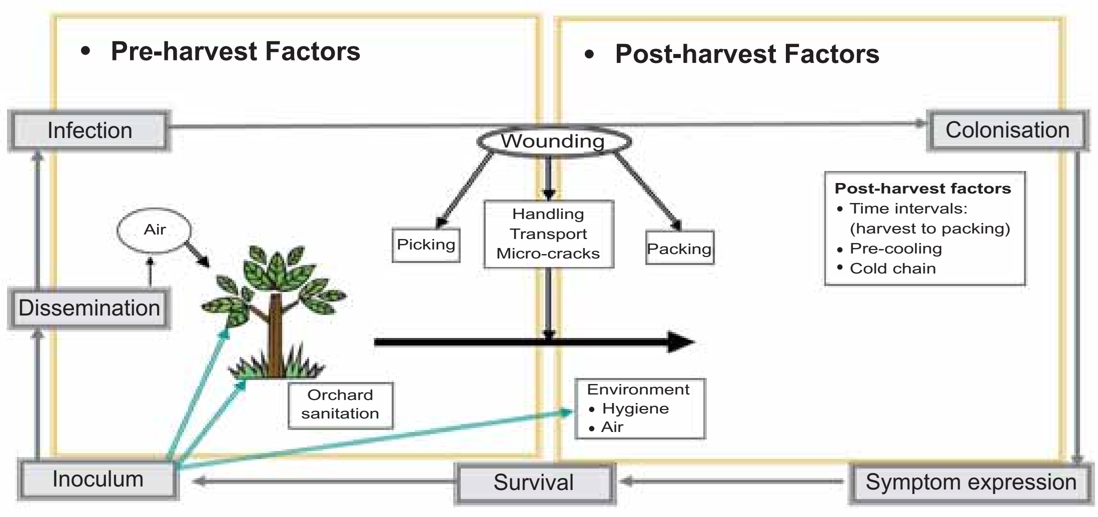
Diseases observed after harvest can be classified on the basis of the stage of occurrence of the different components of the disease cycle:

(1) inoculation or deposition of the inoculum (part of the pathogen such as fungal spores) on the infection court (i.e. host plant or plant product);
(2) penetration;
(3) colonization during which symptoms are produced; and
(4) production and spread of secondary inoculum (Figure VI.2.2).

Pre-harvest diseases begin and complete the disease cycle before harvest whereas post-harvest diseases begin and complete the cycle after harvest. Latent diseases or quiescent infections start the cycle, in particular the inoculation and penetration process, before harvest. The pathogen then becomes dormant mainly because of unfavourable conditions in the tissue of the fruit and resumes growth and proliferates within the fruit tissue after harvest (such as during ripening) thus causing symptoms of the disease. Latent infections cannot, therefore, be detected by visual inspection at the time of harvest. A typical example of a latent infection is mango anthracnose caused by *Colletotrichum gloeosporioides.*

Latent diseases require both pre-harvest and post-harvest control measures whereas diseases initiated after harvest require proper harvest and post-harvest procedures. Produce with pre-harvest diseases can be separated during harvesting and sorting prior to packing.

Figure VI.2.2. Pre-harvest and post-harvest factors that contribute to post-harvest diseases



Source: Korsten, 2008.

Latent disease pathogens may infect the plant through natural openings on the plant or fruit (stomata, lenticel, hydathodes), through wounds, or by active penetration. In the case of diseases initiated after harvest, pathogen infection is usually passive, through wounds and natural openings.

Sources of post-harvest pathogens

Pathogens of latent diseases are strong parasites and occur in the field. Pathogens of diseases initiated after harvest are usually saphrophytes (weak parasites), such as *Cladosporium, Alternaria, Stemphylium, Penicillium, Aspergillus, Rhizopus* and *Mucur*. They are present in packing houses, containers, trucks and cold stores. Soil-borne post-harvest pathogens include *Pythium* rot in tomato and *Erwinia* soft rot in cabbages. These sources of pathogens can be reduced by observing good hygienic practices.

Major post-harvest diseases

Major fungal diseases of fresh fruits and vegetables are as follows:

- *Anthracnose* – This is a serious disease of many tropical fruits, particularly mango, banana and papaya. It is caused by *Colletotrichum* species; *C. gloeosporioides* for mango and papaya, *C. musae* for banana and *C. acutatum* for strawberry. Symptoms include dark brown to black sunken spots on the fruit surface which coalesce at advanced stages of infection.
- *Stem-end rot* – This is another major disease of mango caused by *Lasiodiplodia theobromae* (previously *Diplodia natalensis*). It appears as a black lesion at the stem-end and advances toward the tip of the fruit.
- *Crown rot in banana* – This is caused by a cocktail of pathogens mainly *Lasiodiplodia theobromae, C. musae* and *Fusarium sp.* It is characterized by black lesions at the crown of the banana hand that advance to affect the individual fruit fingers.
- *Fruit rots* – Depending on the causal pathogen, fruit rots include *Aspergillus* rot (*Aspergillus niger*), *Botrytis* rot (*Botrytis cineria*), *Cladosporium* rot (*Cladosporium sp.*), *Penicillium* rots which may be grey mould rot (*Penicillium digitatum*) or blue mould rot (*Penicillium italicum*), *Phomopsis* rot (*Phomopsis sp.*), *Phythophthora* fruit rot (*Phythophthora palmivora*), *Rhizopus* rot (*Rhizopus stolonifer*), and yeast rot. These pathogens are primarily opportunistic in that they infect produce through wounds and natural openings. Symptoms may include dry or wet maceration of fruit tissues which may become depressed and usually with visible mycelial growth of the fungus.

Soft rots are the most important bacterial post-harvest disease and mainly affect vegetables. Soft rots are caused by different subspecies of *Erwinia carotovora* (*Pectobacterium carotovorum*), with subspecies *carotovora* the most common. Other subspecies that cause soft rot include *Atroseptica* and *Chrysanthemi.* All of these pathogens are opportunistic or wound pathogens. Symptoms of soft rots appear as water soaked lesions that become soft and mushy, turn dark and emit a foul odour. Hot and damp weather conditions favour disease development as bacteria require water in order to proliferate.

Spread of diseases in horticultural chains

Fruits and vegetables with disease symptoms are generally discarded during sorting or grading prior to packing or market display. A limited number of infected produce items can, however, be overlooked or can be accepted if they have allowable small lesions. These insignificant lesions can develop further, particularly during lengthy storage or transit periods, either remaining limited to a single commodity or spreading to adjacent commodities.

Control of post-harvest diseases

Post-harvest diseases can be controlled through either cultural, physical, chemical or biological control methods.

Cultural control – Good cultural practices (use of healthy planting materials, field sanitation, appropriate fertilizer and pesticide spray programmes, fruit bagging, tree pruning) and post-harvest practices (proper packaging, storage and transport, sanitation) must be employed as preventive measures against post-harvest diseases. Careful handling is also necessary to avoid physical injury which could predispose produce to disease infection. Other cultural practices, such as harvesting at an optimal stage of maturity, separating diseased produce from sound produce, the use of clean harvesting containers and rapid cooling, should also be observed.

Physical control – Several physical treatments can be applied in order to control pathogen and disease development. These include:

- *Low temperature storage* – The effects of low temperature storage are indirect in that by slowing ripening and senescence, low temperature storage facilitates the maintenance of disease resistance. Low temperatures are also effective in inhibiting pathogen growth.
- *Individial packaging or wrapping* – paper, cloth or plastic wrap can prevent pathogens from entering into produce, thereby reducing the spread of pathogens.
- *Controlled atmosphere (CA)/Modified atmosphere (MA) storage* – low oxygen and/or high carbon dioxide concentrations have both indirect and direct effects on pathogens similar to that of low temperature.

Heat treatment – Hot water and vapour heat treatment can be applied to control fungal diseases. Hot water treatments are commercially used for controlling diseases in mangoes, papayas, mangosteens and bell peppers. Hot water treatment is relatively easily applied, is inexpensive, does not leave chemical residues and is safe to consumers and workers. Dipping in water at a temperature of 45°C for 20 minutes is effective against banana crown rot, whereas a 50 to 55°C water dip for ten minutes is effective against mango anthracnose and stem-end rot.

Vapour heat treatment is a required fruit fly quarantine treatment for mangoes exported to Japan. Other heat treatment systems include dry heat, infrared radiation and microwave radiation treatments. Aside from direct pathogen kill, heat treatment can increase the resistance of produce to pathogens by enhancing the production of antimicrobial compounds and enzymes associated with plant resistance as well as by inducing the production of heat shock proteins.

Irradiation – This treatment destroys DNA leading to cell death in the pathogen and can induce the production of antifungal compounds. A minimum irradiation dose of 1.75 kGy is generally required for disease control.

- *Ozone* – Ozone (O_3) can reduce microbial decay and surface contaminants on fresh produce.

Chemical control – This can be done with the use of chemical pesticides (e.g. fungicides), approved for post-harvest use, natural compounds with antimicrobial properties, and Generally Recognized as Safe (GRAS) chemicals.

- *Chemical pesticides* – a number of chemicals can be applied for post-harvest disease control. Their use should, however, be considered as a last option, since if not totally eliminated they leave toxic residues.
- *Natural compounds* – Some plant extracts, such as ginger, marigold and cinnamon, exhibit antimicrobial activity. Cinnamon extract at 500 ppm was shown to control banana crown rot. Chitosan, a polysaccharide extracted from chitin, a natural substance in the shell of shrimp and crab has been shown to be effective in controlling rambutan fruit rot (*Lasiodiplodia theobromae*), mango *anthracnose*, banana crown rot, and *Botrytis cineria* in strawberries.
- *GRAS compounds*

  Chlorine (as hypochlorous acid) is an effective and economical biocide used in chlorinating wash water in tanks and hydrocoolers. Sodium and calcium hypochlorite are widely applied to disinfect various fruits and vegetables in the packing house.

  Carbonate salts, such as potassium carbonate, sodium bicarbonate (baking soda), ammonium bicarbonate and potassium bicarbonate are commonly used as food additives for controlling pH, taste and spoilage microorganisms and for modifying food texture. These compounds have a broad spectrum of activity against food-borne bacteria and yeasts. They are inexpensive, safe in use and are effective against fungicide-resistant pathogens. Carbonate salts have been accepted for organic ("certified organic") and chemical-free certification for marketing purposes.

  Hydrogen peroxide is a compound that is degraded into O_2 and H_2O leaving no harmful residues. It is considered a GRAS compound by the US Food and Drug Administration (FDA). A commercial preparation, Sanosil-25, which contains 48 percent hydrogen peroxide and silver salt as a stabilizing agent, has been used as a disinfectant.

  Acetic acid and other short chain organic acids such as propionic acid, formic acid and peracetic acid have been commonly used by food manufacturers as antimicrobial preservatives. Vapour of acetic acid can also be used to control post-harvest decay.

Biological control (Biocontrol) – This refers to the use of naturally-occurring microorganisms that antagonize post-harvest pathogens. The use of biological control agents has gained interest because of increased concern about the presence of fungicide residues in foods and the emergence of fungicide-resistant species. Microbial antagonists include fungi *(Trichoderma sp., Cladosporium sp.),* bacteria *(Bacillus substilis, Pseudomonas putida, Pseudomonas syringae pv. lachrymans)* and yeasts *(Acremonlum breve, Debaryomyces hansenii).* The mode of action of antagonists include the secretion of antibiotic compounds (e.g. iturins secreted by *Bacillus subtilis,* pyrrolnitrin by *Pseudomonas cepacia),* competition for nutrients at the wound site (e.g. *Pichia gulliermondii, Crytococcus sp., Metschnikowia pulcherrima, Erwinia cypripedii),* or secretion of enzymes that degrade the cell walls of the pathogens (e.g. glucanase produced by *Pichia gulliermondii,* lytic enzymes such as glucanases, chitinases and proteinases produced by *Trichoderma spp.).*

Novel approaches – Disease resistance can be enhanced with the use of biotic elicitors (e.g. dry mycelium) and abiotic elicitors (e.g. BTH, salicylic acid, jasmonate, acibenzolar, cytokinins and gibberellic acid).

Food safety factors

Toxin-producing microorganisms

During primary metabolism, microorganisms produce substances known as primary metabolites that are essential for their growth. Toward the end of their exponential growth phase, they produce secondary metabolites. Mycotoxins are secondary metabolites of microorganisms.

Mycotoxins are produced by certain fungi and are capable of causing disease and death in humans and other animals. They give the microorganism a competitive edge over other microorganisms occupying the same ecological niche. Numerous species of fungi produce a range of mycotoxins, each of which targets specific cell structures or processes in other microorganisms. The substrate of growth also plays a role in the type and amount of mycotoxin produced. Approximately 300 mycotoxins have so far been described and the majority of these belong to the genera *Aspergillus, Fusarium, Penicillium* and *Alternaria*. Of these, *Aspergillus flavus* and *Aspergillus parasiticus* are the most important.

Fungi that produce mycotoxins are referred to as toxigenic fungi; they are broadly divided into two groups:

- those that produce mycotoxins while still in the field or before harvest – the pathogenic genera involved here are mostly *Fusarium* and *Clavicep*s spp.; and
- those that produce toxins after harvest and during storage – the organisms involved are mainly saprophytic (living on “dead” material). Examples are of the genera *Aspergillus* and *Penicillium*.

Of the known mycotoxins, very few have been recorded as natural food contaminants. Several mycotoxins have, however, been found to be toxic at levels in which they commonly occur as natural contaminants in food items.

Aflatoxin contamination is mainly encountered in tropical and subtropical countries, where environmental conditions are conducive to the development of pathogens. *Citrinin* and *Alternaria* toxin, *tenuazonic* acid, have been found in tomatoes. Other tomato and chili pathogens such as *A. flavus,* which causes *Aspergillus* rot, can also produce aflatoxins, which render infected produce unfit for human consumption. Chilis are generally dried to low moisture content, which is sufficient to prevent fungal growth. This is of particular importance since several fungal species, such as *A. flavus,* attack improperly dried material and can produce toxins such as aflatoxins.

Control of mycotoxin contamination – Toxin producing microorganisms can be controlled through:

- pre-harvest practices that focus on preventing the build up of fungal inoculum and subsequent contamination of the crop during its growth;
- sanitation, harvesting and handling methods that minimize injury to the fruit (wounding, bruising and other injuries to fresh produce must be avoided); and
- storage of fruits and vegetables under dry conditions or in cold storage in order to prevent further fungal growth.

Prevention, elimination and detoxification are therefore the three major approaches to combating the entry of mycotoxins into the food chain.

Pathogenic microorganisms

Food-borne pathogens known to contaminate produce include bacteria, viruses and parasites such as protozoa (Table VI.2.1). Of these, bacteria are of greatest concern in terms of reported cases and seriousness of illness. Although not their natural habitat, most fruits and vegetables contain nutrients required to support the growth of pathogenic and toxigenic microorganisms. Food-borne pathogens are known to be able to attach to fruit surfaces.

Table VI.2.1. Examples of pathogenic microorganisms found in fresh produce

Bacteria	Viruses	Parasites
Salmonella	*Hepatitis A virus*	*Cyclospora*
E. coli O157:H7	*Norovirus*	*Cryptosporidium*
Shigella spp.	*Enteric viruses*	*Giarda*
Aeromonas spp.		*Toxoplasma*
L. monocytogenes		*Helminths- Ascaris*
Klebsiella spp.		
Citrobacter freundii		
Campylobacter spp.		
Vibrio cholera		

Source: Suslow, undated.

Storage temperature and pH are reported to be the two principal determinants of growth for food-borne pathogens associated with fresh produce. Psychrotrophic bacteria, which are organisms that can grow under conditions of refrigeration, vary widely in their acidic tolerances and are the most important spoilage group for fruits and vegetables (Table VI.2.2). The most important of these from a food safety point of view are *Listeria* and *Clostridium*. The fact that these organisms can grow at refrigerated temperatures makes them very important from an export point of view. Beuchat (1998) listed several important food-borne pathogens found in fresh fruit and vegetables and expressed their importance according to frequency of occurrence – *Escherichia coli* 0157:H7 and *Salmonella* were found in more than 8 percent, *Listeria monocytogenes*, 4 to 8 percent, and *Campylobacter*, 3 percent.

Table VI.2.2. Psychrotropic spoilage microorganisms

Bacteria		
Acinetobacter	**Aeromonas**	**Alcaligenes**
Arthrobacter	*Bacillus*	*Chromobacterium*
Citrobacter	*Clostridium*	*Corynebacterium*
Enterobacter	*Erwinia*	*Escherichia*
Flavobacterium	*Klebsiella*	*Lactobacillus*
Leuconostoc	*Listeria*	*Microbacterium*
Pseudomonas	*Moraxella*	*Proteus*
Micrococcus	*Serratia*	*Streptococcus*
Streptomyces	*Vibrio*	*Yersinia*

Source: Bracket, 1993.

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Suggested method of instruction

Lecture using visuals and handouts and discussion.

Practical exercises

Practical exercise V: Controlling microbiological and food safety factors.

Time frame

One hour for the lecture.
Two hours for the practical.

Section VI

Module 3 – Processing water and microbial food safety*

Learning outcomes

The learner should:

- understand the influence of processing water on the microbiological quality of fresh horticultural produce; and
- develop an appreciation of the different water sanitizing treatments for fresh produce.

Introduction

Processing water is that water which is used during the post-harvest handling and marketing of fresh fruits and vegetables. It is used for the preliminary washing of harvested produce in the field, for washing, rinsing or waxing of produce in the packing house, in cooling prior to transport and storage (e.g. hydrocooling), and in some market situations, for the purpose of rehydration or to minimize excessive water loss (e.g. water dipping or misting). In all these post-harvest activities, the intention is to maintain produce quality while enhancing its shelf life and marketability. Processing water can, however, serve as a source of microbial cross-contamination involving both spoilage and pathogenic microorganisms.

This module discusses the different microbial contaminants associated with processing water and water sanitizing treatments applicable to fresh horticultural produce.

Benefits and limitations of processing water

Processing water is used to remove surface dust, soil, latex, other foreign matter and microbial contaminants associated with fresh produce. The efficiency of washing with water varies in accordance with the commodity, type of washing system, type of soil adhering to the surface of the produce, contact time with water, detergent or sanitizer used, and the temperature of the water.

Processing water can, however, remove the natural waxy cuticle that provides the glossy appearance to produce and which serves as a barrier to microbial invasion. Furthermore, it may not always remove microorganisms, and particularly those that become attached to the tissues of produce and those embedded in damaged or adjacent tissues. In situations where recycled water is used, spoilage and pathogenic microflora could build up. Organic residues can also accumulate in wash water, thus providing favourable conditions for microbial growth and increasing the potential for contamination of produce.

Microorganisms associated with processing water

Microbial contaminants of fresh produce often originate in the field and from human sources of contamination and can accumulate in processing water during post-harvest operations. Such microorganisms

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* J. Poubol

include those that cause produce spoilage and human diseases (Table VI.3.1). Human pathogens that have been isolated from wash water include *Escherichia coli, Salmonella sp., Vibrio cholerae, Shigella sp., Cryptosporidium parvum, Giardia lamblia, Cyclospora cayetanensis, Toxoplasma gondii,* Norwalk and hepatitis A viruses. Table VI.3.2 shows produce items associated with disease outbreaks caused by these pathogens, their sources and infection doses.

Table VI.3.1. Sources of on-farm microbial contamination of fresh produce

Sources of contamination	Produce item	Microflora
Seeds	Sprouts	*Salmonella, Bacillus cereus*
Soil, organic matter	Rhizospheres (root vegetables)	*Clostridium perfringens*
Irrigation (overhead system)	Tomatoes	Bacteria
Pesticide (mix with contaminated water	Inoculated fresh fruits and vegetables with pathogens	*Salmonella, Shigella, E. coli* O157:H7 survival and growth in the pesticide
Insects	Damaged fruits and vegetables	Spoilage and pathogenic microflora
Organic fertilizer (cattle manure)	Vegetables	Spoilage microflora, *Salmonella, E. coli* O157:H7

Source: Lamikanra, 2005.

Table VI.3.2. Some pathogenic microorganisms associated with fresh produce

Micro-organism	Incubation period	Symptoms	Infection dose (number of cells)	Source	Examples of produce associated with outbreaks
1. Bacteria					
E. coli O157:H7	2 to 5 days	Watery diarrhea often containing blood, abdominal pain, can lead to hemolytic urenic syndrome and kidney failure especially in children	10 to 1 000	animal faeces especially cattle, deer	alfalfa sprouts, apple cider, lettuce, radish sprouts
Salmonella sp.	18 to 36 hours	Abdominal pain, diarrhoea, chills, fever, nausea, vomiting	10 to 100 000	human and animal faeces	alfalfa sprouts, apple cider, melons, tomatoes
Shigella sp.	1 to 3 days	Abdominal pain, diarrhoea, fever, vomiting	10	human faeces	lettuce
2. Parasites					
Cryptosporidium sp.	1 to 12 days	Profuse watery diarrhoea, abdominal pain, anorexia, vomiting	<30	human and animal faeces	apple cider
Cyclospora sp.	1 to 11 days	Watery diarrhoea, nausea, anorexia, abdominal cramps (duration: 7 to 40 days)	unknown, probably low	human faeces, others	basil, lettuce, raspberries
3. Viruses					
Hepatitis A	25 to 30 days	Fever, malaise, anorexia, nausea, abdominal pain, jaundice, dark urine	10 to 50	human faeces and urine	lettuce, frozen strawberries

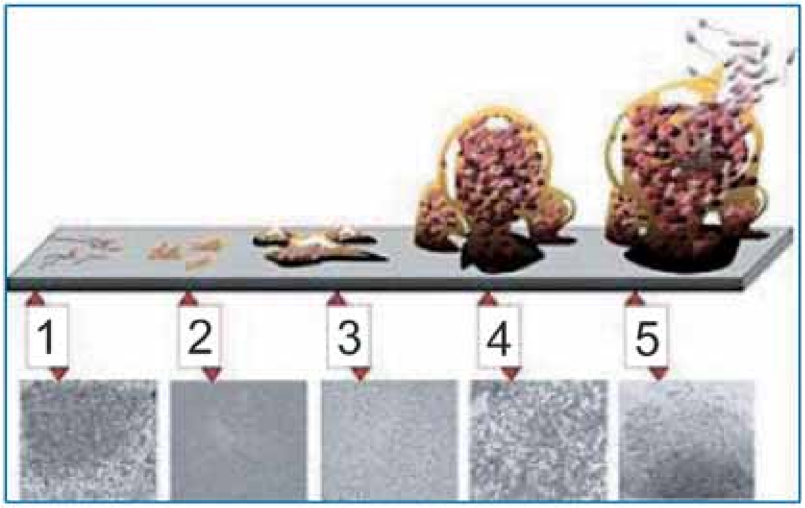
Source: Harris, 1997.

Biofilms and microorganisms

A biofilm is a complex aggregation of microorganisms marked by the excretion of a protective and adhesive matrix. Biofilms are characterized by surface attachment, structural heterogeneity, genetic diversity, complex community interactions and an extracellular matrix of polymeric substances.

Biofilms are present on everyday household products such as cutting boards, kitchen sponges and dish cloths, and can be found on almost any surface where sufficient nutrients and water are present. Pathogens such as *Pseudomonas* (Figure VI.3.1), *Salmonella, Staphylococcus*, and *Bacillus* can form biofilms which can serve as a continuous source of contamination if not removed or properly disinfected. Biofilms can build up in packing house dips and wash baths. Microorganisms within established biofilms can withstand nutrient deprivation, pH changes, oxygen radicals, disinfectants and antimicrobial compounds and can tolerate high concentrations of sanitizers. Biofilms can be controlled physically (ultrasound or mechanically) and chemically. Although physical methods have been proven to be more successful than chemical methods, it is difficult to supervise the effectiveness of these methods.

Figure VI.3.1. Five stages of *Pseudomonas aeruginosa* biofilm development



Key:
1 – initial attachment;
2 – irreversible attachment;
3 – maturation I;
4 – maturation II;
5 – dispersal.

Source: www.en.wikipedia.org

Sanitization of processing water

Washing in potable water containing a sanitizing agent can significantly reduce the microbial load associated with fresh produce. This should be a part of GAP, GHP and GMP programmes.

A sanitizing agent or sanitizer is an antimicrobial agent applied to destroy or reduce the number of microorganisms of public health concern, without affecting produce quality and consumer safety. Sanitizers minimize the transmission of pathogens from water to produce, reduce the microbial load on the surface of the produce, and prevent microbial buildup in the processing water.

Desired properties of a sanitizer include the following:

- ability to effect complete sterilization;
- reactive and breaks down easily in the presence of organic matter;
- harmless to humans and animals;
- inexpensive;
- non-corrosive; and
- effective in removing biofilms.

Sanitizers applied to fresh fruits and vegetables must be safe in use and must be used in accordance with given instructions. The sanitizer concentration in the processing water should be routinely monitored and adjusted to prescribed levels. Should it not be possible to monitor the sanitizer concentration, recommendations for the reuse of sanitized water should be followed. In order to minimize the buildup of organic materials, the water must be filtered, or otherwise changed. Technical assistance on the use of sanitizers should be sought when necessary.

Chlorine-based sanitizers

Chlorine is the predominant sanitizer used in the food industry. It is used in the sanitization of fruits, vegetables and fresh-cut produce. Chlorine is also used to sanitize the surfaces of processing facilities and to reduce microbial populations in water used during cleaning and packing house operations.

Commercially used forms of chlorine – Some chlorine-based sanitizers are relatively inexpensive and are readily available as they are used in daily life. These sanitizers include:

- *S*odium hypochlorite (NaOCl) – This is a common source of chlorine used in small-scale operations. It is widely available as commercial bleach (5.25 percent or 12.75 percent NaOCl) in the liquid form. Excess sodium can build up in recirculating water and can damage sensitive produce. The addition of NaOCl can result in an increase in the pH of water to more than 7.5.
- *C*alcium hypochlorite ($Ca(OCl)_2$) – This is generally sold in the form of a granulated powder or compressed tablets. It is the most common source of chlorine used for disinfecting produce and processing water. It increases the pH of water to slightly above 7.5. Phytotoxicity (bleaching or burning) can occur if the granules fail to dissolve in a hydrocooler system.
- Chlorine gas (Cl_2) – This is the least expensive but most demanding form of chlorine from the safety and monitoring standpoint. It is generally restricted for use in very large-scale operations. The use of chlorine gas requires automated, controlled injection systems with on-line pH monitoring. Chlorine gas reacts with water to form hypochlorous acid and hydrochloric acid. It reduces the pH of water to below 6.5.

Chlorine levels in post-harvest sanitation – Recommended levels of total active chlorine for fresh fruits and vegetables generally vary between 100 and 300 *u*g/ml. Table VI.3.3 provides examples of specific uses of chlorine in post-harvest operations and the target microorganisms. The judicious use of chlorine is, however, recommended as it could lead to the production of chloroform ($CHCl_3$). A number of countries have developed protocols that make use of low levels of chlorine in washing and sanitizing operations. In some European countries (Belgium, Germany, Netherlands, Switzerland), measures to ban the use of chlorine are now being undertaken.

Table VI.3.3. Examples of post-harvest uses of chlorinated disinfectants in fresh fruits and vegetables

Timing	Application/Example	Rate (*u*g/ml)	Primary target microbes or benefit	Use
Harvest equipment	General sanitation	50 to 150	Bacteria, fungal spores	Common
Butt spray	Celery, lettuce	150 to 200	Prevent bacterial rot and enzymatic browning	No longer common
Head spray	Cauliflower	50 to 100 with plastic overwrap	Prevent floret browning, bacteria, fungi and enzymatic browning from harvest damage	Common
Drench tanks	Wash water sanitation	50 to 400	Bacteria, fungal spores	Common
Dump tanks and flotation tanks	Tomato, pepper, citrus, apples, pears	50 to 400	Bacteria, fungal spores, surface microbial load reduction	Common
Flumes	Tomatoes, sweet potato	150 to 200	Bacteria, fungal spores	Common
Wash spray bars	Wash water sanitation	75 to 150	Bacteria, surface microbial load reduction	Common

Table VI.3.3. *(continued)*

Timing	Application/Example	Rate (*ug*/ml)	Primary target microbes or benefit	Use
Hydrocooler	Cooling water sanitation	50 to 300	Bacteria, surface microbial load reduction	Common
Abrasive peelers	Wash water sanitation	50 to 200	Bacteria, surface microbial load reduction	Common
Fresh-cut vegetables	Wash and cooling water sanitation	50 to 200	Bacteria, surface microbial load reduction	Common
Packing line sanitation	Conveyer belts, pads, diverters, etc.	Chlorinated water spray or foams	Biofilm prevention, general microbial reduction on contact surfaces	Limited
Misting lines and nozzles	Water sanitation, distribution centres, retail display	5 to 10	Biofilm prevention, coliform elimination	Common
Retail trim and wash	Wash water sanitation	25 to 50	Bacteria, surface microbial load reduction	Not common

Source: Suslow, No date.

Alternatives to chlorine

Chlorine dioxide (ClO_2) – This is a water-soluble yellowish green gas, with an odour similar to that of chlorine. It does not hydrolyze in water and is unaffected by pH (6 to 10) changes. It does not react with organic matter to form chloroform. It has been approved for use in flume waters in fruit and vegetable operations by the United States Food and Drug Administration. Its oxidizing power is 2.5 times that of chlorine. Chlorine dioxide is effective against many microorganisms at lower concentrations than free chlorine. It is highly effective at neutral pH. Its reactivity is, however, reduced by the presence of organic matter.

Chlorine dioxide is more costly than chlorine. It cannot be transported and must be generated on-site. In addition, simple assays for routine evaluation of concentration are not available. Chlorine dioxide may produce hazardous bi-products such as chlorite (ClO_2) and chlorate (ClO_3). Its noxious odour is toxic to humans. Microbial susceptibility to chlorine dioxide depends on the microbial strain and environmental conditions during application. Chlorine dioxide can be used on processing equipment at a maximum level of 200 ppm whereas for whole or uncut produce it can be used at a level of 3 ppm.

Acidified sodium chlorite (ASC, $NaClO_2$). This is a chlorine-based sanitizer synonymous with SANOVA® and forms chlorous acid ($NaClO_2 + H^+$ --- $HClO_2$), which has a strong oxidizing capacity. Chlorous acid further breaks down to chlorite, which does not result in the formation of THMs. This sanitizer has been approved by United States Food and Drug Administration and the United States Environmental Protection Agency for application on fruits and vegetables, including fresh-cut produce by spraying or dipping in 500 to 1 200 ppm solution.

Ozone (O_3) – This is a water-soluble gas with broad and rapid biocidal activity. It has strong oxidizing capacity and high reactivity and penetrability. It is, however, unstable under ambient temperature conditions. Ozone rapidly undergoes spontaneous decomposition under conditions of high pH (>8), leading to the production of oxygen, which is a non-toxic product. Ozone must be generated on-site from air.

Gaseous ozone is toxic to humans (>4 ppm). The maximum permissible level for short-term exposure is 0.3 ppm in air. It is corrosive to common materials, thus stainless steel should be used. Ozone must be filtered in order to remove organic and particulate materials. Ozone has been given a Generally Recognized as Safe (GRAS) status for use in food contact applications. Concentrations of 1 ppm or lower in water and short contact times are sufficient to inactivate bacteria, moulds, yeasts, parasites and viruses. An ozone concentration of 0.5 to 4 ppm is recommended for wash waters, whereas for flume water an ozone concentration of 0.1 ppm is recommended.

Electrolyzed water – This may come in the form of acidic electrolyzed water (AEW) or neutral electrolyzed water (NEW). AEW is known as electrolyzed oxidizing water and is strongly acidic (pH of 2.1 to 4.5). It contains HOCl as an antimicrobial component. AEW is used widely in Japan. AEW has biocidal effects against *E. coli* O157:H7, *S. enteritidis, L. monocytogenes* and biofilms. The bactericidal power of AEW is higher than that of a 5 ppm ozone solution in the decontamination of fresh-cut lettuce.

NEW on the other hand has a neutral pH (close to 7.0). It contains between 15 and 50 ppm of available chlorine obtained from 2.5 percent NaCl. It is generally two to three times more effective than NaOCl.

Factors affecting the efficacy of sanitizers

The efficacy of a sanitizer depends on:

- *Type and pH of sanitizer* – Sanitizers should be used within the pH range in which they are most effective.
- *Time and type of contact* – Chlorine is most effective within a few seconds of treatment.
- *Water temperature* – Water temperature should be higher than that of the produce in order to avoid the uptake of microbial cells by the produce tissues.
- *Properties of the produce* – These include the type of produce, surface structure and their interaction with the sanitizer.
- *Properties of the microorganisms* – These include the type of microbial cells, resistance of the micro-organism, and level of contamination. Heavily contaminated produce should undergo preliminary washing to remove heavy soil followed by a second wash to sanitize the produce.

Practices to maintain water quality

- Periodically test water.
- Properly set water change schedule.
- Clean and sanitize water contact surfaces (dump tanks, flumes, wash tanks, and hydrocoolers).
- Install backflow devices between potable water fill lines and dump tank drain lines.
- Regularly inspect and maintain equipment to maintain water quality (chlorine injectors, filtration systems, backflow devices).
- Set an audit verification system (e.g. USDA GAP and Good Handling Practices).

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Suggested methods of instruction

Lecture using visuals or handouts and discussion.

Practical exercise

Practical exercise V.3: Monitoring microbial contamination and hygiene.

Time frame

45 minutes for the lecture.
One hour for the practical.

Section VI

Module 4 – Entomological factors that impact on quality*

Learning outcomes

The learner should:

- understand the impact of insects on horticultural chain management;
- become familiar with the most important insect pests that affect horticultural produce; and
- become familiar with measures to control insect pests in horticultural chains.

Introduction

Insect pests are important in the international trade of fresh fruits and vegetables in Asia and the Pacific region. Fresh produce imports that have not been subjected to approved disinfestation treatments are banned by many countries. Even within countries, the shipment of produce from pest-infested areas to pest-free areas is prohibited if strict quarantine procedures are not followed. Insect pests can cause serious economic losses because of lost market opportunities, as well physical losses.

This module introduces the major insect pests of fruits and vegetables in the region and management strategies to control these pests.

Insect pests of fresh produce

Insect pests are either field or storage pests. Field insect pests can cause total crop failure or yield loss. They can be carried undetected in harvested produce causing losses in quantity, quality and marketability. Storage pests (e.g. weevils) occur post-harvest. Apart from causing losses in produce, insect pests can cause the spread of plant and human disease pathogens.

Oriental fruit fly

The Oriental fruit fly (*Dacus dorsalis*) is the most important insect pest in Asia and the Pacific region and infests mainly fleshy fruits and vegetables. It is also the main pest of concern in the international trade of horticultural produce from the region, and particularly tropical fruit. The adult insect has a lifespan of one to two months whereas the egg, larva and pupa have lifespans of one to two, seven to eight, and seven to nine days, respectively.

Other fruit flies

Other fruit flies of lesser importance than the oriental fruit fly include the melon fruit fly (*D. cucrbitae*) that infests tomato and cucurbits and the Queensland fruit fly (*D. tryoni*) that infests many deciduous and subtropical fruits in the Pacific islands and Australia.

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* B. Chankaewmanee

Weevils

The mango seed weevil (*Sternochetus mangiferae*) and sweet potato weevil (*Cylas formicarius*) are the leading weevil-pests in the region. Since infestation occurs within the mango fruit or sweet potato tuber, the weevil cannot be detected by visual inspection of the fruit. The mango seed weevil poses a major constraint to domestic and international trade of the fruit.

Other insect pests

Moths, mites, mealy bugs and scale insects are among the economically important insect pests of fruits and vegetables in the region.

The major moths are the codling moth (*Cydia pomonella*) in apple, pear, peach, prune and walnut and the bean pod borer (*Maruca testulalis*) in vegetable legumes.

The major mites are the potato tuber mite (*Phthorimeae operculella*) that infests potatoes, tomatoes and eggplants, European red mite (*Panonychus ulmi*) that attacks apples and other deciduous fruit and the red-legged earth mite (*Halotydeus destructor*) that attacks leafy vegetables grown in Australia and New Zealand.

The citrus mealy bug (*Planococcus citri*) attacks citrus and grapes and the pineapple mealy bug (*Dysmicoccus bevipes*) attacks pineapples.

Red scale (*Aonidiella aurintii*) and purple scale (*Lepidosaphis beckii*) insects attack citrus.

Pest management measures

Quarantine disinfestation

Gaining market access requires adherence to the quarantine regulations of importing countries. Exporters can seek advice from quarantine authorities in importing countries about pests that are prohibited and protocols for disinfesting produce before it can be imported into those countries. In accordance with rules of the World Trade Organization, countries are entitled to impose quarantine restrictions in order to prevent the introduction of pests and diseases that could adversely affect their horticultural industries.

Technologies that may be successfully used to disinfest fresh produce include methyl bromide fumigation, dipping or spraying with specific insecticides, heat or cold treatments, the use of controlled atmospheres and ionizing radiation. The use of methyl bromide is being phased out because of its effect on depleting the global ozone layer. Methyl bromide is still, however, approved under increasingly strict conditions for quarantine treatments where there is no satisfactory alternative. Systemic insecticides are also being phased out because of increased concerns about the potential adverse effects of their residues on human health. This leaves physical hot or cold treatments, controlled atmosphere treatments and ionizing radiation as the key disinfestation options. Care must be taken to assure that disinfestation treatments kill the insect pest with little or no detrimental effects on the visual and eating quality of the fresh produce item.

A typical quarantine treatment imposed by importing countries is vapour heat treatment (treatment at 47^{o}C for 20 minutes) for mangoes exported to Japan. The technique initially faced the problem of increased internal breakdown in the fruit flesh but was later addressed when the treatment was coupled with immediate cooling.

Cold treatment

Storage at 1 to 3°C for 14 days is effective in killing the Queensland fruit fly but can only be applied without causing physiological injury to cold tolerant produce such as stone and pome fruit. Subtropical fruits could be amenable to this treatment without developing chilling injury but the duration of the treatment must be reduced. The cold treatment can be reduced by about one week with the addition of 95 percent CO_2 to the storage atmosphere for the first one to two days without a detrimental impact on quality.

Heat treatment

A core temperature of 47°C for a specified time period (e.g. 15 minutes) is required to kill fruit flies and some other insect pests. Most fruits are damaged by prolonged exposure to temperatures exceeding 45°C. The duration of high temperature treatments must, therefore, be kept to the minimum required to kill the insect pest.

Hot water or vapour heat may be used to rapidly heat produce because of the higher heat capacity of water. Immersion in hot water may lead to anoxia (oxygen starvation of cells) in larger fruit such as mangoes. Vapour heat treatments have been commercially adopted for the treatment of mangoes and rambutans because there is less interference with gas exchange.

Rapid heating can be achieved with microwave radiation but has not been found feasible on a commercial scale given that heating is highly variable depending on the structure of the fruit and is not evenly distributed in packed fruit. The application of microwave heating is limited to produce such as nuts that have low water content.

Controlled atmosphere (CA) treatment

Low oxygen and high carbon dioxide concentrations in combination with low temperatures can control insect pests and are a potential alternative to methyl bromide fumigation. An oxygen concentration of 3 percent or less, coupled with high carbon dioxide levels is generally used for CA disinfestation treatments. These atmospheric conditions are generally supplemented with appropriate temperature and relative humidity conditions to maintain the quality of fresh produce (CA storage). Insect infestation is controlled by maintaining low oxygen concentrations for an extended period of time, leading to reduced metabolism of the insect. Susceptibility to this treatment is affected by the developmental stage of the insect. Pupae and larvae, for example, are more sensitive than are eggs and adults. CA can, however, compromise produce quality at higher temperatures.

Ionizing irradiation

Although the use of ionizing radiation is regarded as a mature technology and a safe procedure, it has not been widely adopted because of adverse consumer perceptions and the cost of applying the technology. The Codex Alimentarius General Standard for Irradiated Foods (2003) provides for absorbed dosages to food not exceeding 10 kGy. A dose of approximately 150 Gy is required to sterilize insects (Table VI.4.1). Most fruits, with the exception of avocados suffer no damage from these low dose treatments. Much higher doses are, however, required to kill insects, inhibit ripening, and inhibit fungal diseases. These high doses generally exceed the tolerance of fresh produce tissues. The use of other treatments in combination with irradiation to enable the use of safe doses of irradiation should, therefore, be explored. This is now being worked out in countries like Thailand to meet industry requirements for an irradiation treatment for produce destined for export. Renewed interest in irradiation is primarily because of the phasing out of hazardous chemical treatments such as methyl bromide treatments and the growing food safety concerns of consumers.

Integrated pest management

Integrating or combining different pest management treatments can enable the use of suboptimal and safer levels of each treatment. CA treatments are generally used in combination with hot or cold treatments to shorten the duration of these treatments and to reduce their negative effects on produce quality. An integrated or systems approach to pest management, involving at least two treatments that act independently but with a cumulative effect, has been prescribed by FAO. This approach relies on sound knowledge of pest and host biology and may include a number of components, such as:

- quarantine pest identification and risk management measures;
- pest surveillance, trapping and sampling;
- cultural practices;
- field treatment;
- post-harvest disinfestation;
- use of non-hosts or resistant hosts, including harvest maturity;
- pest-free areas; and
- limited harvest and shipping periods.

Table VI.4.1. Comparison of maximum tolerable and minimum radiation doses required for desired technical effects on selected fresh produce

Produce	Desired technical effect	Maximum tolerable dose (kGy)	Minimum dose required (kGy)
Apple	Control scald and brown core	1 to 1.5	1.5
Apricot, peach, nectarine	Inhibit brown rot	0.5 to 1	2
Asparagus	Inhibit growth	0.15	0.05 to 0.1
Avocado	Inhibit ripening and rot	0.25	-
Banana	Inhibit ripening	0.5	0.30 to 0.35
Lemon	Inhibit Penicillium rots	0.25	1.5 to 2
Mushroom	Inhibit stem growth and cap opening	1	2
Orange	Inhibit Penicillium rots	2	2
Papaya	Disinfest fruit fly	0.75 to 1	0.25
Pear	Inhibit ripening	1	0.25
Potato	Inhibit sprouting	0.2	0.08 to 0.15
Strawberry	Inhibit grey mould	2	2
Table grape	Inhibit grey mould	0.25 to 0.50	-
Tomato	Inhibit Alternaria rot	1 to 1.5	3

1 Gray = 100 rads

Source: Maxie et al (1971)

Other strategies

Non-host status – Commodities may be exported if they are shown to be non-hosts of a quarantine pest for all or part of its life cycle – this means that, an insect cannot complete its life cycle on the produce. The non-host status of a commodity can, however, be difficult to establish.

Pest-free area (PFA) – These are areas in which specific quarantine pests do not occur and which are kept free of those pests. Distribution of the Mediterranean fruit fly is, for example, is limited to some areas in Australia, others being free of that pest. Export from these fruit fly-free areas is permitted by some importing countries.

Pest eradication – Eradication of a pest involves the elimination of all individuals of a species from an area where recolonization is unlikely to occur. Eradication efforts are generally targeted at introduced pests to eliminate them from a given area or to prevent their further spread. Techniques for pest eradication include the sterile-insect technique (SIT) and male annihilation technique (MAT). In such cases, the treated area must be isolated – males from untreated areas should not be able to migrate to treated areas, for example.

- Sterile-insect technique (SIT) – involves the release of many males that have been sterilized by radiation or chemical means in the target areas. These mate with wild females and produce non-viable offspring. This technique is used worldwide.
- Male annihilation technique (MAT) – is based on the manipulation of male behaviour. It involves the use of many traps with insecticide-laced lures that attract and kill large numbers of males of a particular species, reducing the opportunity for females to mate.

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Suggested methods of instruction

Lecture using visuals or handouts and discussion.

Time frame

One hour.

SECTION VII

Handling operations and facilities to assure quality maintenance in horticultural chains

Section VII

Module 1 – Maturity indices and harvesting*

Learning outcomes

The learner should:

- understand harvest maturity, its indices, and impact on fresh produce quality; and
- understand proper timing and method of harvest and field handling of harvested produce in small and commercial operations.

Introduction

Fresh produce quality cannot be improved after harvest, it can only be maintained. It is, therefore, important that fresh produce is harvested at optimum maturity and peak quality in the proper way, if it is to satisfy consumer needs for quality. Four factors must be considered at harvest: stage of maturity; method of harvesting; time of the day of harvesting; and handling of harvested produce in the field (or field handling). Any deficiency in these factors results in partial or total loss of quality.

This module describes the different indices of harvest maturity and the proper procedures in harvesting and field handling to obtain safe fresh produce of good quality.

Harvest maturity

Produce harvested at the optimum stages of maturity has a good post-harvest life and quality attributes desired by consumers. Produce harvested when in an immature state is susceptible to water loss, handling damage and pathogenic attack. It lacks taste and flavour, and in certain circumstances, fails to ripen. Produce harvested when over mature is soft, of poor texture and eating quality and is susceptible to pathogenic attack.

Different markets require different types of produce at different stages of maturity. It is, therefore, essential that the maturity index or indices for a specific market are known. The composition (sugars, starch, acids) and changes during development, physiological development (climacteric or non-climacteric, including the role of ethylene), and possible indices for optimizing harvest time (e.g. days from bloom, seed, skin or flesh colour, starch or soluble solids) using taste panels after storage must be determined wherever possible. Representative random sampling should be employed when assessing maturity.

Physiological and commercial maturity

Produce may be harvested in accordance with its physiological maturity, or its commercial maturity.

Physiological maturity – This is the stage in the development of a plant or plant organ when maximum growth has been achieved. Physiological maturity can be objectively determined on the basis of maximum

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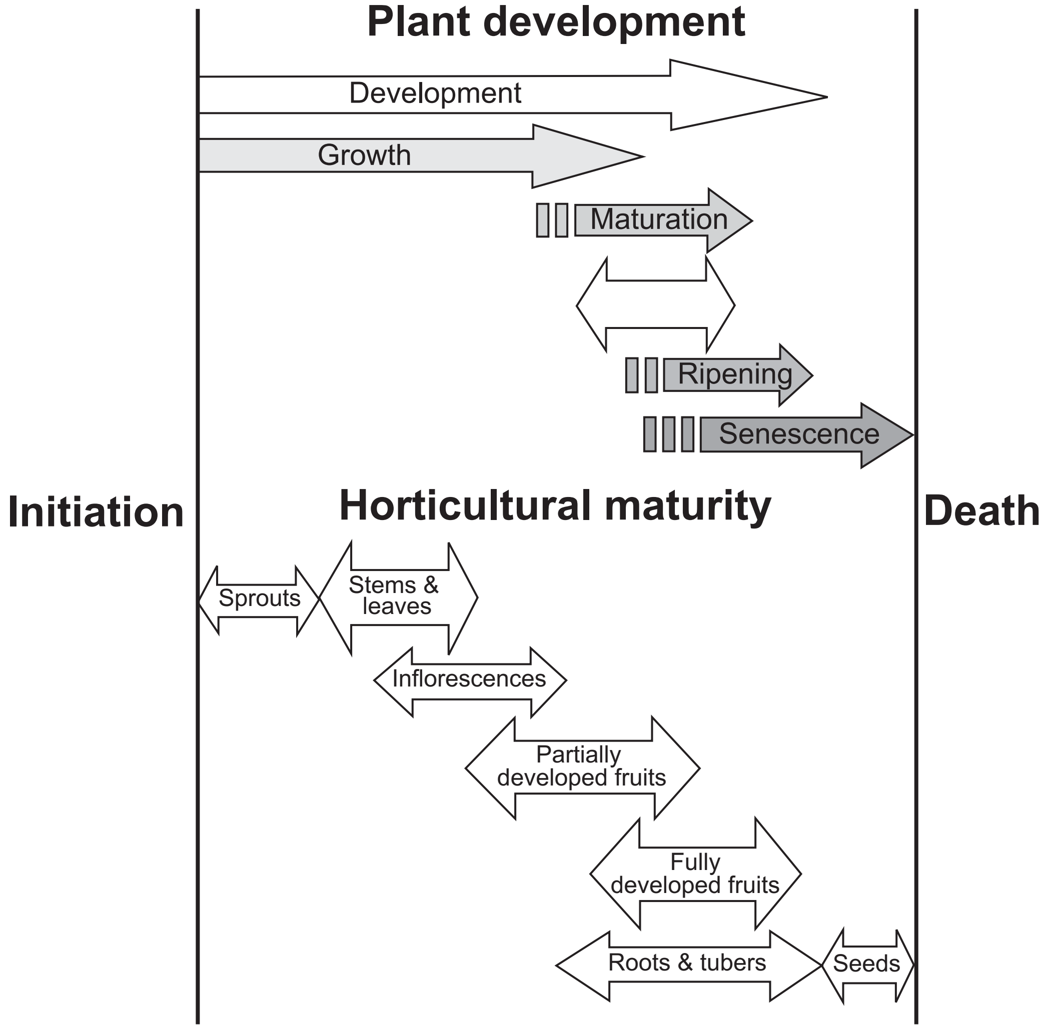
dry matter accumulation. It may be manifested by visible signs such as yellowing at the tip of papaya fruit or production of bloom on the surface of mango fruit.

Commercial or horticultural maturity – This is the stage in the development of a plant or plant organ when it meets market and consumer requirements. Baby corn and pickling cucumber are commercially mature at the size required by the market. Produce is both commercially and physiologically mature at the maximum dry matter content which is also desired by the market. Commercial maturities of fruit and vegetables are shown in Figure VII.1.1.

Figure VII.1.1. Commercial maturity in relation to stage of development of horticultural crops



Harvest maturity indices

The maturity index of a fruit or vegetable provides an indication of its stage of development or maturation. Maturity indices are based on characteristics that are known to change as the fruit matures. Maturity indices for harvest can be either subjective or objective (Table VII.1.1). For a specific crop, one or more indices could be used to determine optimum harvest maturity.

Subjective maturity indices

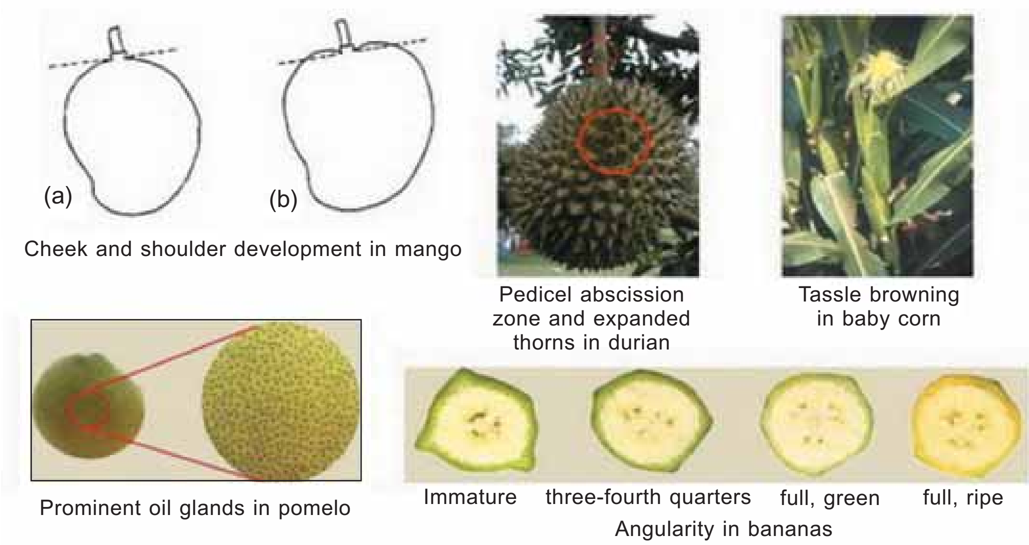
Subjective indices rely on the experience of the grower. Indices, such as size, shape and colour charts and pictures, have been used in developing objective automated methods for assessing maturity.

Table VII.1.1. Subjective and objective indices of harvest maturity for horticultural crops

Subjective maturity indices	Objective maturity indices
Appearance – colour, size and shape	Total soluble solids (TSS)
Touch – texture, hardness or softness	Titratable acidity (TA)
Smell – odour or aroma	Ratio of TSS: TA
Resonance – sound when tapped	Firmness
Sweetness – sourness, bitterness	Oil content
Days from planting or flowering	Dry matter
Others: appearance of gloss, drying of pedicels	Starch content

Shape and size – Some fruits and vegetables develop characteristic shapes or sizes when ready for harvest. Mangoes, for example, develop bulging cheeks and shoulders; bananas become less angular when mature but still green; durian has a swollen abscission zone at the junction of the pedicel and fruit and expanded thorns; the oil glands in pomelo increase in prominence aside from the peel turning from green to yellow green; while the tassles in baby corn begin to turn brown (Figure VII.1.2). In commercial farms that grow bananas for export, the width of individual fingers is used to determine harvest maturity. The maximum width of a finger located in the middle of the bunch is measured with the use of callipers. This measurement is referred to as calliper grade.

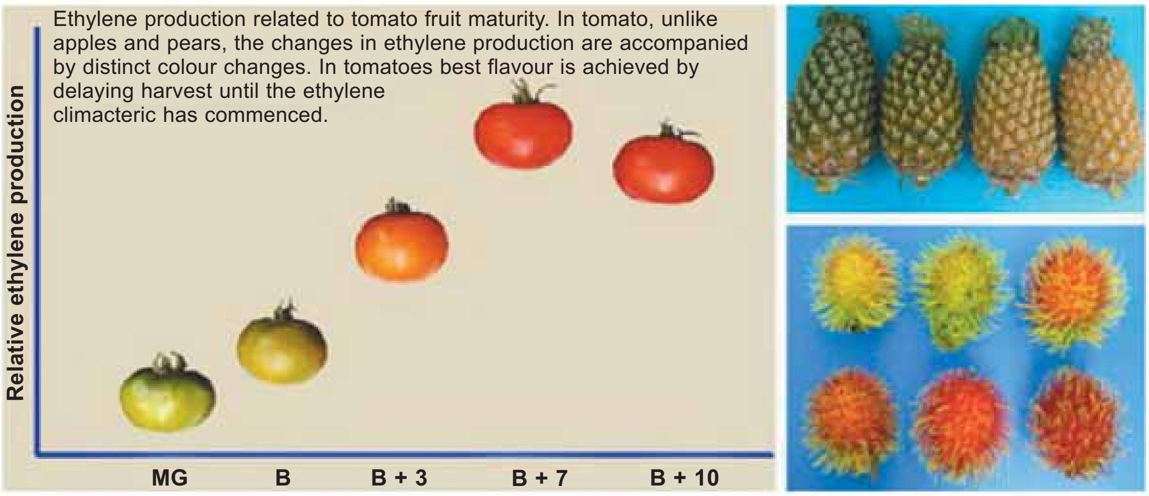
Figure VII.1.2. Shape and size changes for some fruits and vegetables at maturity



Source: KMUTT, 2007.

Peel colour – This is the most obvious indicator of harvest maturity, particularly for fruits to be harvested at different stages of ripening (Figure VII.1.3). Tomatoes can be harvested at either the breaker, pink or firm-ripe stage. They can also be harvested at the mature green stage, especially if destined for distant markets or if longer storage periods are required after harvest. Being climacteric, mature green tomatoes can ripen normally and develop optimum quality characteristics. In contrast, immature fruits will fail to develop full colour and flavour and will deteriorate easily. Mature-green fruits can withstand rough handling during shipping. They may not, however, attain the desired degree of ripeness on arrival at the point of sale. In such cases, additional holding is required for normal ripening to occur or artificial ripening treatments become necessary. Pink or red-ripe fruits are generally desired by consumers and processors.

Figure VII.1.3. Colour changes with maturity and ripening of tomato, pineapple and rambutan



Source: KMUTT, 2007.

Other climacteric fruits such as papaya, peaches and plums can be harvested when the peel colour associated with ripening appears. In non-climacteric fruit which do not have the capacity to continue ripening after harvest, colour changes to red or yellow (e.g. rambutan, strawberry, longan, longkong and peppers) are a dependable index of harvest maturity. Citrus grown in tropical climates and some cultivars of avocado, however, remain green even when fully ripe. Colour changes in some pineapple cultivars vary in accordance with climate and fertilizer practices.

Number of days from planting or flowering – This has been commercially used by mango growers to harvest mature green Çarabao mangoes (or Super Manila mango) after 110 to 120 days from full bloom. Some leafy vegetables are harvested after a certain period from transplanting combined with plant size. Mustard greens are, for example, harvested after 25 days from field planting but with the desired size to meet market requirement. Harvest dates are reliant on a reproducible date for the time of flowering and relatively constant growth period to maturity, which may not be consistent from year to year.

Other subjective indices – Volatile compounds synthesized during ripening give fruit their characteristic odour and provide an indication of the level of maturity. Jackfruit produces a sweet aroma when ripe.

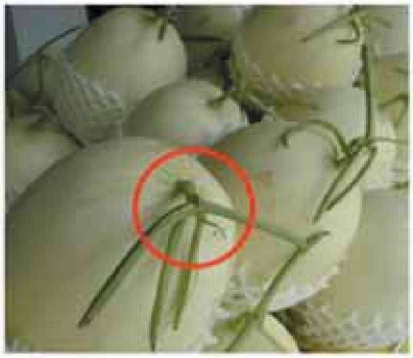
Acoustics – The sound emitted (resonance frequencies) by the fruit when gently tapped by hand can also help judge maturity in durian, watermelon and jackfruit. Commercial acoustic and resonance detectors have been developed for use in mechanical grading.

Pedicel drying – The extent of pedicel drying can be used as an index for evaluating the maturity of honeydew melons that do not abscise (Figure VII.1.4). In most cantaloupes, an abscission zone develops at the junction of the pedicel and the fruit. The fruit separates (slips) from the parent vine by the time it reaches the climacteric in ethylene production. Harvesting cantaloupe melons at full slip stage ensures that they are fully mature with desired quality attributes.

Bloom Production – Mangoes and mangosteens develop a whitish bloom or gloss on the skin surface when mature (Figure VII.1.4).

Compactness (solidity, firmness) – Compactness of heads is used to determine harvest maturity of cabbage and Chinese cabbage. A compact head can only be slightly compressed with moderate hand pressure. Delaying harvest even a few days beyond maturity can result in split or cracked heads and increased incidence of rots. Immature heads are puffy or have hollow spaces since the inner leaves are not fully developed and hence, loosely arranged, which make them susceptible to damage. When harvested at an immature stage, yield weight is also lower and shelf life is shorter than that of mature heads.

Figure VII.1.4. Pedicel drying in honeydew melon and bloom production in mango and mangosteen



Pedicel drying in honeydew melon

Production of gloss or bloom in mango and mangosteen

Source: KMUTT, 2007.

Tenderness – Leafy greens such as mustards and amaranth are harvested on the basis of the tenderness of their leaves, plant size and number of days after planting. These greens must be harvested when the leaves have developed to full size and are not so advanced in age that the leaves are tough and bitter in flavour.

Objective maturity indices

Colour measurements – The use of electronic colorimeters (Figure VII.1.5) under standardized conditions reduces human error in colour measurement. Measurements at several points on the produce surface are required to obtain reliable data. Changes in colour are best expressed as hue angles or chroma, which are calculated on the basis of raw data measurements (a*, b*).

Figure VII.1.5. Colorimeter for colour measurement

The hue angle correlates to the colour perceived by the human eye whereas the chroma provides a measure of the intensity of the colour. On-line colour sorting machines that function in a manner similar to laboratory equipment are widely used in commercial packing houses to grade citrus, mangoes, tomatoes and apples in accordance with their colour.

Soluble solids content – Measurement of the sugar content provides an indication of when fruit have attained an appropriate level of sweetness. Soluble solids are measured using a refractometer (Figure VII.1.6) and are expressed as a percentage of total soluble solids content (TSS or SSC). TSS or SSC measurements are not usually used as a single index of maturity.

Figure VII.1.6. Refractometer for TSS measurement

Minimum SSCs for some fruits are: 10 percent for apple, apricot and watermelon; 14 to 16 percent for cherry; 6.2 percent for kiwifruit, 16 to 17 percent for litchi; 15 percent for papaya and 12 percent for pineapple.

TSS or SSC is influenced by factors such as irrigation, the nutritional status of the plant, weather conditions, and the position of the fruit on the tree.

Firmness – This is measured with the use of a penetrometer or pressure tester (Figure VII.1.7). Penetrometer readings provide an indication of fruit storage performance. In many instances packing house operators refuse fruit for long-term storage if penetrometer readings are below a specified level. In apples, for example, firmness should be 14 lb force. Firmness is affected by seasonal and orchard variability, tree vigour, fruit size, fruit nitrogen and calcium content, and growth regulators.

Figure VII.1.7. Firmness testers

For tomato | For mango | For apple plus starch test

Starch content – This is measured by the iodine test which provides a reliable indication of starch distribution in the fruit and thus an estimate of the degree of starch conversion to sugars (Figure VII.1.8). The fruit is cut in half and dipped in an iodine solution. Iodine reacts with starch, resulting in a blue to black colour. The stained pattern is compared to a rating scale and an average rating is calculated as the starch index. Iodine solutions (2 percent) can readily be sourced from a local chemist. During fruit storage, the starch test can be performed on a weekly basis or more frequently depending on the expected ripening rate.

Figure VII.1.8. Starch measurement and rating system by iodine test

Common rating scale for starch:

1. = Full starch (all blue-black)
2. = Clear of stain in seed cavity and halfway to vascular area
3. = Clear through the area including vascular bundles
4. = Half of flesh clear
5. = Starch just under skin
6. = Free of starch (no stain)

Juice content – The juice content increases with maturity in many fruits. Juice content is determined by extracting juice from a representative sample using standard juice extraction procedures. The volume of extracted juice is related to the original mass of the fruit and is proportional to its maturity. The minimum juice content of citrus fruits is 40 percent for clementines, 35 percent for grapefruit and other oranges, 30 percent for navel oranges, 33 percent for mandarins, and 25 percent for lemons.

Oil content – Oil content can be used to determine the maturity of fruit such as avocados. Oil content is determined by weighing a 5 to 10 g sample of pulp and extracting oil using a solvent (e.g. benzene or petroleum ether) in a distillation column. The determination of oil content has been successfully used for cultivars that are of high oil content.

Dry matter content – This is also used to assess the maturity of avocadoes as well as kiwifruit. It is usually measured by oven-drying of a known weight of sample to a constant weight.

Acidity – The acidity of many fruits changes progressively during maturation and ripening. In general, acidity decreases as fruit mature on the tree. Acidity can be measured by titration against a standard base using phenolphthalein as an indicator. The sugar to acid ratio (or TSS: acid) is often better related to fruit palatability than either individual measurements of sugar or acid levels alone.

Specific gravity – Specific gravity is the relative gravity or weight of solids or liquids as compared to water (specific gravity = 1) at ambient temperature. It increases as fruits mature. Specific gravity measurements are used to assess the degree of maturity of mangoes by placing fruits in water (with or without 3 percent salt) in a container. Fruits that sink (sinkers) are more mature than are those that float (floaters).

Maturity indices for selected crops

Harvest maturity of some fruit and vegetables are given above according to specific subjective or objective indices. Tables VII.1.2 and VII.1.3 provides the possible indices that can be combined to determine harvest maturity of specific produce items.

Table VII.1.2. Maturity indices of selected fruits

Apple	Banana
• Textural properties – firmness, tenderness, starch and sugar content • Burst of internal ethylene production	• Top leaves start to dry out • Colour of axis of fruit fingers changes from dark to light green • Brittleness of floral ends should fall with slight touch • Fruit becomes less angular • Days from emergence of inflorescence: 95 to 110 days • Pulp to skin ratio – 120: 1.2
Citrus	**Mango**
• Change in colour (green to orange) • Ease of separation • Starch content • Rate of respiration • Days from blooming • Seed colour (green to brown) • Change in organic acid • Juice content (>50 percent)	• Slight colour development of shoulder • Fullness of shoulders • Pedicel colour change from green to brown • Faster drying of latex from fruit stalk • Days from full bloom • Appearance of bloom on fruit surface • Heat units in degree days • Change in lenticel morphology • Specific gravity of >1.0
Papaya	**Pineapple**
• 33 percent colour development for long-distance market and 85.5 percent for local market • Yellow to purple colour development	• Yellowing • TSS (13 percent); acidity (0.5 to 0.6 percent); TSS: acid (21 to 27) • Tips of bracts projecting as the eyes start drying • Spacing between eyes increased.

Table VII.1.3. Maturity indices of selected vegetables

Asparagus	Cabbage and Chinese cabbage
• Spears grow above ground • Spears not too long, before tops begin to spread	• Compactness/solidity of heads • Days from field planting (depends on cultivar and growing condition)
Peppers (bell/hot chili)	**Carrots**
• Ripening fruit: breaker to full red or yellow • Mature green fruit: full size; shiny surface	• Size is the primary factor; at least $^{3}/_{4}$ diameter • Proper colour development, without zoning
Cauliflower	**Okra**
• Curd size and condition before heads become discoloured, loose, “ricy” (granular) or blemished • Over-mature curds too long, fuzzy and “ricy”	• Pods young and tender, full size • Pods that are too mature are fibrous and tough
Peas	**Tomato**
• Sugar content >5-6 percent, sugar declines with maturity; ratio of starch to protein increases • Tenderness and appearance of pods – should be well filled but young and tender • Colour from dark to light green • Firmness of 5 kg/cm^2	• Mature green, pink or breaker (just starting to turn red) and red ripe • Pulp surrounding the seeds is jelly-like; seeds slip away from the knife (mature green)

Harvesting method

Proper harvesting is essential to avoid physical injury which provides points for the entry of pathogens. Appropriate harvesting tools and containers must be used in order to avoid damage during harvesting. Those involved in harvesting operations must be educated about the perishability of produce. An incentive system for harvesters based on quality is also useful.

Manual harvesting

Fruits and vegetables are generally manually harvested in Asia and the Pacific region. Manual harvesting is advantageous in minimizing damage. Manual harvesting also facilitates selective harvesting, i.e. only produce with the desired maturity is picked. In situations where fruits are located high up on trees, climbing and reaching out for the fruit slow harvesting operations. Allowing fruit to fall to the ground can result in damage and bruising, resulting in soft patches that could lead to rejection at quality assurance checkpoints.

A picking pole with a receptacle (net or bag) is preferred for manually harvesting fruit from tall fruit trees such as mango trees and papaya trees. The fruit is collected into the receptacle and is subsequently transferred to a container conveniently positioned in the tree. When filled, the receptacle is lowered to a receiver on the ground. This operation should be facilitated with the use of a ladder.

In the case of large tree fruits such as durian and jackfruit, the fruit is tied before picking, placed in a sack and lowered to the ground.

Fruits and vegetables from smaller plants can be harvested by hand alone or using tools such as knives, clippers and scissors. Fruits must not be pulled from the plant.

Leafy greens must be carefully uprooted whereas other leafy vegetables should be carefully cut at the base with a sharp knife in order to reduce effort and reduce picker fatigue.

For fruits and vegetables that require repeated harvests per season, care must be observed not to damage the plant or the immature, developing produce for the succeeding harvest.

Worker safety during manual harvesting

Pickers must wear appropriate clothing and must make use of protective gadgets. During the harvesting of okra or tomatoes, for example, pickers should wear long-sleeved shirts, hand gloves and face masks to avoid contact with the trichomes of the fruit or plant which can cause allergic reactions. The same should be worn when picking hot chili fruit as the oils (capsaicin) can cause severe burns. Pickers should be careful not to touch the face or eyes.

Harvesting aids

Harvesting aids can significantly reduce labour costs, improve harvesting efficiency, speed up harvesting, and help maintain produce quality. In addition to picking poles, ladders, knives, clippers and scissors, harvesting aids include containers and a simple modified farm trailer for transporting produce from the field to the packing house. Rigid containers, such as wooden and plastic crates, and plastic buckets can be used as field collection containers. Containers must have smooth surfaces. Containers with sharp edges should be lined with available materials, such as fresh leaves, sacks or used newsprint. A cotton waist bag or small bucket tied to the waist of the picker can be used as a harvesting container. The bag can be designed to open at the bottom for emptying and transferring the produce to field containers. These containers must be clean. In situations where labour is scarce, conveyers can be used to load the harvest into the collection container. Conveyors reduce the cost of harvest and increase the efficiency of harvest operations.

Mechanical harvesting

Mechanical harvesting reduces labour and management costs, resulting in savings as high as 30 to 45 percent. Mechanical harvesters are primarily designed for a shake-catch action, which helps to detach the fruits by shaking or vibrating trees or bushes. Given that mechanical shakers have no means of detecting quality, even carefully adjusted harvesters will harvest significant quantities of unacceptable fruits. Immature, overripe, diseased and damaged fruit, which would ordinarily be discarded by a human picker, are often harvested by mechanical harvesting. Elimination of unacceptable fruit and foreign matter is difficult and costly. Mechanical harvesting can also result in relatively high levels of losses because of damage. Mechanical harvesting is, therefore, only recommended for large-scale operations where labour is scarce and expensive.

Time of harvesting

Fresh produce must be harvested at cooler times of the day preferably early in the morning, taking advantage of the lower temperatures which minimize the heat load of produce and which increases the work efficiency of pickers. Harvesting should begin when morning dew has evaporated to avoid damage to the produce because of turgidity. In situations where produce must be harvested very early in the morning (e.g. dawn), care must be taken to avoid damage to plants or produce for subsequent harvesting. In exceptional situations where produce must be harvested when the sun is up, harvested produce should be transferred to a shaded area, and the heat allowed to dissipate.

Fresh produce must not be harvested during or just after rains, as wet conditions favour microbial growth and enhance the breakdown of produce. Rain water can accumulate on produce creating favourable conditions for microbial growth. If harvesting cannot be avoided under rainy conditions, produce must be properly washed and dried. Washing and drying are critical in situations where soil particles that may contain pathogenic microorganisms, adhere to the fruit.

The quality of leafy greens can be affected by time of harvest. Pakchoi has its highest water content at 04.00 hours and at 20.00 hours, resulting in a slower rate of wilting. Harvesting pakchoi later in the day has an added advantage since sugar levels are higher as a result of photosynthesis during the day. This can slow down leaf yellowing which has been associated with sugar depletion.

Field handling of harvested produce

Fresh produce must never be dropped into harvesting and field containers if field injury is to be avoided. Large containers are generally used in order to facilitate the handling and transportation of produce from the farm to the packing house. The use of plastic crates for this purpose is recommended, but low-cost containers such as bamboo crates can be used. When bamboo baskets or wooden crates are used, they must be lined with fresh banana leaves or old newspapers in order to protect the produce from any sharp surfaces in the container. Other faulty practices during field handling, such as throwing produce into the container and dropping and dragging containers during hauling should be avoided as these can result in both visible and non-visible physical injuries.

Harvested produce must be kept under shade to avoid exposure to excessive heat that could result in sunscald, rapid water loss leading to wrinkling or wilting, and accumulation of field heat. Produce left under the sun will heat up rapidly. This heat is later released and may cause heating inside the packaging container, transport load or storage area and can also increase the refrigeration load. Field heat must be removed through precooling operations (see packing house operations).

Produce harvested at different stages of maturity can be sorted in the field by either placing them in separate containers or in collecting containers equipped with improvised dividers. Sorting according to size and freedom from defects can also be done simultaneously if experienced pickers are employed. Produce is otherwise delivered to the packing house for these operations.

Other field handling operations include packing for immediate transport to the market, delatexing in the case of latex-producing produce, and in the case of bananas, dehanding or detaching individual fruit hands from the bunch and placing them on padded trailers for transport to the packing house. On some banana plantations fruit bunches are tied to a cable system that transports them to the packing house.

In the case of leafy vegetables, water loss (2 to 3 percent water loss) may be purposefully imposed. Pakchoi is, for example, exposed to the sun for 30 minutes immediately after harvest. This treatment significantly reduces mechanical damage (snapping of turgid outer leaves) when packing the produce into bamboo baskets. Wilted pakchoi can be re-hydrated (and cooled) by dipping in water and the general appearance, colour and original weight could be restored if moisture loss is less than 10 percent.

Exposure of cabbage heads to the heat of the sun, with the butt up for about an hour after harvest, facilitates drying of the cut butt end, minimizing bacterial pathogen infection.

Hygienic management of harvesting tools, equipment and accessories

Harvested produce must not come into contact with soil or contaminated surfaces, e.g. surfaces that are visibly contaminated with dirt, oil or chemicals. It must be transferred gently to collection bins and protected from sun or rain until such time that it can be transported to the packing house. Containers used for field collection must be clean and smooth, with no sharp edges or projections to damage the produce. They must not be overfilled.

Torn bags, broken boxes and other containers used in harvesting must be repaired if produce damage is to be avoided. Wooden splinters from containers, for example, could cause wounding of produce. Broken equipment is also difficult to maintain in a hygienic condition since small cracks provide ideal niches for microorganisms, which may cause decay or food safety problems.

Field equipment must be checked for soundness, and accounted for. If a knife blade is broken, the harvester's batch number must be traced and the produce must be properly checked to prevent physical contamination.

Regular cleaning of all field equipment is essential. Tools must be washed daily in soap solution or sanitized water. The cleaning interval for large items of field equipment such as large collection containers will vary in accordance with the type of produce harvested. It is generally recommended that harvesting bags be washed at the end of the harvesting season and harvesting crates should be washed daily to remove dirt and debris. Crates used for mangoes should be washed on a daily basis to remove the latex secretions from the stem-end of the fruit; if not removed regularly, the mango crates will become stained and soiled, which could pose a food-safety risk. Field equipment must be stored in a closed facility that is protected from rats and birds, which are sources of microbial contaminants.

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Suggested methods of instruction

Lecture using handouts or visuals and discussion.

Practical exercise

Practical exercise IV: Evaluating fresh produce quality.

Time frame

1.5 hours for the lecture.
3 hours for the practical.

Section VII

Module 2 – Packing house operations and packing house design*

Learning outcomes

The learner should:

- understand the different packing house operations and their impact on produce quality;
- develop an appreciation of good hygienic practices and record keeping in the packing house; and
- understand important features of packing house infrastructure and design.

Introduction

A packing house is an important facility for transforming produce from single units to packaged units for storage, dispatch and marketing. Packing house operations may include, cleaning, sorting, grading, commodity treatments (chemical or non-chemical), packing and temporary holding in shaded and ventilated space or cold storage room. A packing house must, therefore, be designed to enable the multiple operations for a specific produce item and must be conveniently located to allow for the receipt of produce and its shipment to market destinations.

This module describes the different packing house operations and key features of packing house infrastructure and design.

Packing house operations

Produce flow

Depending on the produce type, the flow of activities in the packing house may be as follows:

- inspection and documentation for produce traceability;
- bin tipping or dumping;
- cleaning (trimming, dry brushing, washing);
- application of fungicide, waxing, drying;
- sorting to discard damaged, unripe, over-ripe, misshapen produce;
- size and colour grading;
- packing and labelling;
- cooling and storage;
- loading on to trucks; and
- dispatch.

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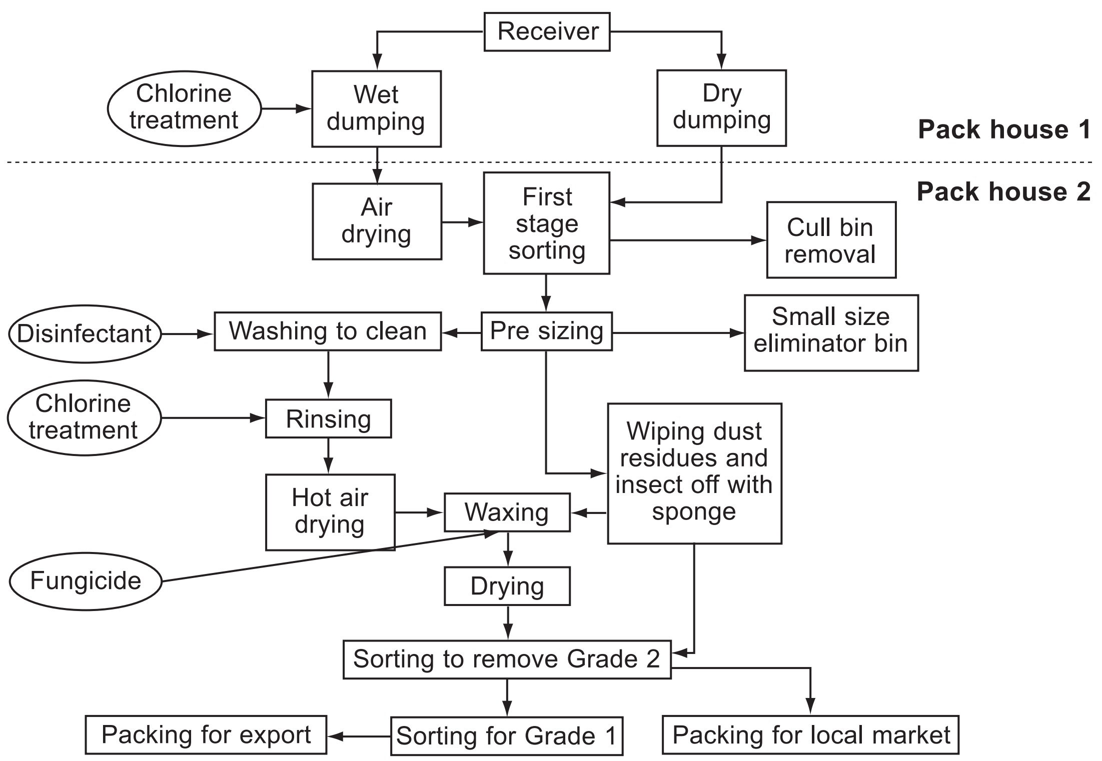
Figure VII.2.1 illustrates the flow of packing house activities in two stages designated packing house 1 and packing house 2:

Packing house 1. The packing house is an accumulation centre for produce from the field. Information on production area (based on the location of produce on the farm), date of harvest, picker name (for the purposes of AsiaGap) and local records are gathered in packing house 1. Produce is then off-loaded into water or padded dry dumps and then cleaned.

Packing house 2. Preliminary sorting is performed in order to remove injured, decayed or defective produce and to minimize the spread of infection to other produce. This may be followed by cleaning, sorting and grading, produce treatments, packing and stacking, and dispatch with or without prior storage.

Figure VII.2.1. Different packing house operations for fruit



Source: Kader, 1993.

Cleaning

Cleaning minimizes microbial contamination, reduces physical damage and transport cost, and enhances produce quality and market appeal. Produce can be cleaned by washing, dry brushing and wiping. In fruits with attached peduncles at harvest (e.g. mango, Figure VII.2.2a), the peduncle or fruit stalk (which may puncture neighbouring fruit) is trimmed prior to washing in order to remove latex stains (Figure VII.2.2b). In the case of leafy vegetables, some leaves are removed (e.g. wrapper leaves of cabbages retaining three to four leaves for protection) and the stem is trimmed. In some banana packing houses, alum is added to water used in preliminary washing in order to facilitate latex removal (Figure VII.2.2c). Dry brushes are used to clean bulky produce such as potatoes, other root vegetables, kiwifruit and avocado. For produce such as tomatoes, cleaning may be done by wiping with the use of a dry cotton cloth.

Produce must be washed in clean water containing an appropriate concentration of sanitizer in order to minimize the transmission of pathogens and reduce the pathogen load in the wash water. Pathogens are likely to contaminate produce in dump tanks, washing lines, as well as during grading and pre-cooling. Chlorine is generally used to sanitize water. The concentration of free available chlorine in the water and the pH of the water must be specified (Section VI, Module 3).

Figure VII.2.2. Mango with peduncle (a) and latex stain (b) and washing of bananas to remove latex (c)

(a) (b) (c)

Source: KMUTT, 2007.

Maintaining water temperature below 10°C reduces microbial growth in the wash tank. Produce from the field is usually at a high temperature and is susceptible to microbial entry via natural openings in the skin. Pre-washing in cold water can minimize that problem.

Segregation

The purpose of segregation is to remove produce that does not meet quality specifications, create uniform lines of produce, and adhere to grade standards for specific markets. Produce is segregated on the basis of uniformity in size, shape and taste, freedom from defects, and minimum quality variation. Mechanized segregation reduces labour requirements, minimizes error, and increases operating efficiency. Simple sizing machines can be used (Figure VII.2.3) in small packing houses. In more advanced packing houses, modern grading machines are used, such as the Compac segregation equipment for colour, weight and sugar content (Figure VII.2.3), which can sort 10 to 12 fruit per second per lane maximum of 40 lanes. This modern equipment is used for specific market niches to optimize returns and to facilitate marketing. Consumers want minimum quality variation and will pay for consistent quality lines. In addition to colour, weight and sugar content, fruit is sorted on the basis of density and the presence of defects.

Treatment of produce in the packing house

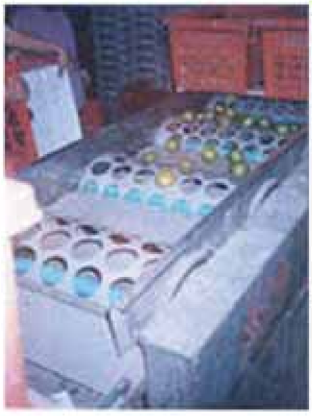
Other packing house operations designed to maintain produce quality during marketing, include:

- *Pre-cooling* – This is done to remove field heat.
- *Short heat treatments* – For example, hot water dips, to kill insect pests and pathogens (Figure VII.2.4). If used properly, short heat treatments can delay fruit ripening and can improve the quality of crops such as asparagus, mangoes, apples, peaches and nectarines.
- *Other disease control treatments* – Lime or alum treatments can control cabbage soft rot.
- *Ripening treatments* – These are used to regulate ripening. Ethylene or its analogue (e.g. acetylene) is used for rapid and uniform ripening and anti-ethylene compounds such as MCP are used to delay ripening.
- *Waxing* – This is used to slow physiological deterioration and improve appearance.

Other packing house operations

Packing is the main packing house operation. Fresh produce can also be stored in the packing house in order to maintain quality and even out shipments. Packing and packaging operations are elaborated in a separate module (Section VII, Module 3).

Figure VII.2.3. Grading machines used to segregate produce based on size (simple sizing equipment), colour (computerized monitoring of hue angle), weight and sugar content (brix)



Size

Color

Weight

Brix

Figure VII.2.4 Commercial hot water treatment facility for mango

Record keeping

Domestic and international trade requires traceability to enable diagnosis of problems and to identify best growing practices. Packing houses must keep records of food safety incidents (e.g. chemical residues exceeding the maximum residue level set by a particular country), corrective actions taken, time when corrective actions were taken, and entity undertaking the action. Packing houses should supply buyers and/or government officials with records that enable them to trace back to a particular orchard soon after a request has been received, particularly in situations where food safety is at risk. For this reason, packing houses should keep detailed records of each carton packed for export, including grower/producer details, orchard number or location, details of the fruit variety/cultivar and chemicals used on produce in the packing house.

Process control

Monitoring of produce on the packing line is best done using a statistical sampling or chart technique. Quality factors should be monitored and rapid adjustments or corrective actions should be promptly made. Statistical analysis of data gathered from samples collected following the sorting operation provides valuable information on grading and sorting, different growers or fields and processing methods.

Good hygienic practices in the packing house

Good hygienic practices are important in the handling of food to be consumed. A high level of general and personal cleanliness is essential, requiring hair coverings, removal of rings and earrings, protective clothing and footwear for workers. No smoking, eating or drinking is observed in areas where fresh produce is handled. Injuries should be reported and treated immediately to prevent product contamination. No one with a contagious disease should be allowed in the produce-handling areas until given a clean bill of health.

Doors to and from produce handling areas should be kept closed in order to limit potential contamination by animals and birds. Chemicals should be sealed and stored in a locked area identified by a hazard sign and should never be used after their expiry date. Expired chemicals should be disposed of in a place and manner that does not harm people or the environment. Waste product and spent chemicals should be placed in closed containers and disposed of properly.

The packing line and all surfaces that come into contact with produce areas should be routinely cleaned and sanitized using approved sanitizers with strict observation of the manufacturers' instructions. Any debris in the packing line must be physically removed using a top-to-bottom approach to avoid re-soiling of cleaned surfaces. The packing line should be left free of produce every day. All closed surfaces must be sanitized using fumigants that are safe in use.

The packing house facility

A packing house is a facility where fresh produce is cleaned, sorted or graded, and packed. The packed produce can then be pre-cooled before storage or assembly usually in pallets stabilized by strapping with strong plastic taping or plastic netting. These units are moved by fork lift truck or hand lift truck into a cool room for further cooling and short-term storage or directly onto a truck for transport to market destination. Packing houses can be located on-farm, and thus managed as part of the commercial farming operation (usually larger commercial operators), or are otherwise owned co-operatively or privately.

Location of the packing house facility

Critical factors to be considered in identifying the site for packing houses are as follows:

- *Level of pollution* – The area should have minimal risk of water or air contamination. The history of the site on which the packing house is to be located must, therefore, be known.
- *Support infrastructure* – Electricity, water and sewage disposal facilities are critical requirements for commercial packing house facilities.
- *Accessibility* – The area must be centrally located, close to farms, and must be well connected to the road network, with direct access to ports (sea or air), markets or manufacturing plants.

Infrastructural design and standards

The size and design of the packing house and the level and scale of equipment with which it is equipped are dependent on the type and volume of produce to be handled, market requirements, access to infrastructure, and capital cost.

Packing house surroundings. The packing house must be easily accessible and must have well-paved and clean surroundings with good drainage and adequate space for vehicles to manoeuvre during on- and off-loading of produce and other materials.

A temporary waste holding area can be marked or built to separate waste from other areas of the packing house premises.

Hygienic factors in packing house design. Packing house design must integrate considerations for basic food safety requirements.

1. *Floors* must be finished, preferably with impervious material (e.g. polymer, epoxy resin), safe to walk on when wet, sealed in production areas, sloped for quick water run-off to the internal drainage system.
2. *Walls* must be smooth and free of cavities to prevent debris from lodging and harbouring pests and must facilitate surface cleaning (painted epoxy coating or sealed sheeting can be used as wall or floor lining). They must not be fitted with protrusions or shelves.
3. *Windows* should ideally be made of stainless steel; if made of glass, they must be shatterproof or plastic coated to prevent glass splinters from contaminating the produce if broken. Wooden windows are not recommended. Windows must be screened to keep out insects and birds.
4. *Ceilings* must be suspended to ensure there is no exposed roof structure over the packing area. If not suspended, roof joints must be regularly cleaned to prevent the build-up of dust or dirt.
5. *Lighting* must be adequate, particularly above grading and sorting areas. Light fixtures must be covered with a shatterproof plastic diffuser or with sleeve covers.
6. *External doors* must be lockable. Doors must be kept closed in order to prevent the entry of pests. Rubber swing doors or overlapping plastic strip curtains must be used in areas where forklifts move frequently. All doors must be closed at night.
7. *Noticeboards* must be posted far from the packing area and must be covered with perspex sheets (not glass) to prevent pins or other contaminants from getting into the produce.
8. *Pre*-cooling facilities are best placed in the vicinity of the unloading area to keep incoming produce. The size of the pre-cooling facility and the volume of produce to be stored at any one time should be considered in selecting the refrigeration unit.
9. *Cold storage facilities*, especially their walls and floors, must be easily cleaned.
10. *Worker sanitation facilities* (toilet and hand washing facilities) must be adequate and comply with legal requirements with a door separating them from the packing area; adequate and clean hand washing facilities, including wash basins that can be cleaned regularly and will not break easily, preferably both hot and cold water, soap containers, paper towel dispensers and/or hot air blowers are also required.

Floor plan design

The general product flow in the packing house must be well planned to ensure that produce moves efficiently through the facility without any opportunity for cross contamination. The generalized features of floor plan design (Figure VII.2.5) must include the following:

Floor plan lay-out for packing facility

This should consist of:

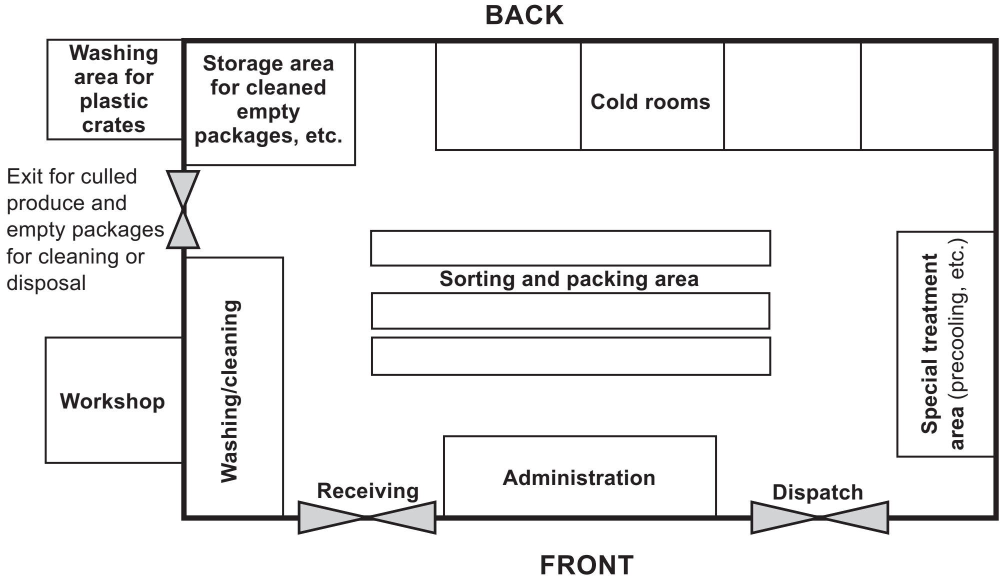
- receiving area – space for initial sorting to remove wounded, diseased and unmarketable produce should be elevated so that produce can be unloaded easily;
- washing area – should have a dump tank for initial cleaning and cooling and/or spray washer/brusher;
- area for grading and sizing;
- stations for specific post-harvest treatments – sorting, hydrocooling, waxing;
- area for packing produce; and
- area for off-loading produce.

Floor plan lay-out for administration, storage and maintenance

This should consist of:

- area for storage of empty containers and other materials;
- area for administration office;
- reception area; and
- small workshop for general maintenance (e.g. repair broken pallets, etc.).

Figure VII.2.5. Example of a packing house floor plan



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Suggested method of instruction

Lecture using handouts or visuals and discussion.

Practical exercises

Practical exercise III.3: Visit to a packing house.

Time frame

One hour for the lecture.
Three hours for the practical exercise.

Section VII

Module 3 – Packing and packaging*

Learning outcomes

The learner should:

- develop an appreciation of the importance and principles of fresh produce packaging;
- develop an appreciation of the different types of packages that are suitable for fresh produce handling; and
- understand the approach to selecting appropriate packaging systems for specific produce items.

Introduction

Packaging is critical to the success or failure of horticultural chains. Proper packaging systems are required in order to facilitate handling and distribution, preserve quality and improve the marketability of fresh produce. Proper packaging also determines initial and repeat purchases of fresh produce.

Packaging is a coordinated system for preparing fresh produce for safe, secure, efficient and effective handling, transport, distribution, storage, retailing, consumption and recovery, re-use or disposal combined with maximizing consumer value, sales and profit.

A package is the container or material that contains the produce. It may be a primary, secondary or tertiary package, retail package/consumer package, or transport package.

Packaging material is the material used in making packages.

Packing material is anything other than the produce that is included inside the package.

Packing is the act of arranging or organizing produce within a package.

This module introduces the importance and basic principles of packaging of fresh fruit and vegetables, factors to be considered in designing packages, and packaging decision tools.

Packaging functions and considerations

Packaging provides three basic functions:

- *Protection* – It protects the produce from mechanical injury and undesirable environmental conditions (temperature, humidity and atmospheric gases).
- *Utility* – In addition to containing the produce, the packaging system should extend the shelf life of produce, enhance convenience in produce handling and use, and be environmentally-friendly.

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* K. Tanprasert

- *Communication* – Packaging provides both required and optional information to the customer and consumer.

Package design integrates both structural and graphic elements. Structural design takes into consideration the protection of fresh produce from mechanical damage and quality loss and the utility of the package, and graphics design takes into consideration the text, picture, texture, material, and colour of the package.

Factors that must be considered when designing a packaging system for fresh produce:

- *Produce characteristics* – The produce size, weight, respiration rate, requirements for special treatment (e.g. pre-cooling, washing), storage temperature and humidity requirements, and sensitivity to mechanical forces (compression, shock or impact, vibration and cut) determine the size, shape, strength, material, and ventilation required in a package.
- *Distribution* – The mode of transportation (method of cost calculation, time required to reach destination, temperature control and protection from mechanical injury), unit size and customer identification must be considered.
- *Regulatory requirements* – Regulations of producing countries or those of the destination market govern the selection of a packaging system. These regulations provide for information that should be provided on the package, packages allowed in use, package treatment and package waste.
- *Customer/marketing requirements* – Packaging requirements differ for export, domestic and local supply chains.

Packaging materials and packages for fresh produce

Fresh fruits and vegetables are commonly packaged in containers made from wood, paper and plastics. Other packaging materials for fruits and vegetables include plant leaves (e.g. palm leaves woven into baskets), fibres (e.g. jute sack material), and metal (e.g. metal buckets or basins mainly used as harvesting and hauling containers). Bags or sacks are mainly used for produce that is resistant to damage, such as potatoes, onions and garlic.

Wooden packages

Wood has been used for a long time and it is still being used for the packaging of fresh produce. Wooden packages come in various shapes, sizes and capacities (Figure VII.3.1). Baskets or hampers are woven from veneer of bamboo or timber and change shape easily when subjected to vertical or horizontal compression. Wooden packages provide good protection against compression and their strength is not affected by moisture. They can be fabricated with ventilation holes and with holders to facilitate handling, with metal reinforcement to increase strength, and with provisions for stacking to prevent stack failure. They can be made collapsible when empty by fastening individual wooden slats with common wires or metal fasteners. Their surfaces may, however, be rough if not properly planed. The construction of wooden packages is time consuming and requires special skills. Labelling of wooden packages and disposal after use is difficult. Furthermore, wooden packages are expensive and heavy and are consequently being replaced by corrugated board and plastic containers.

Wood is also used in the production of pallets for the unitized handling of containers of produce (Figure VII.3.2). Standard pallets usually measure 1.067 to 1.219 metre (42 to 48 inches) in length and 0.8 to 1.14 metre (31.5 to 44.88 inches) in width depending on the country or region where they are produced. Guidelines for regulating wooden packaging material in international trade must be followed in order to prevent the spread of pests from international shipments. Heat treatment to a core temperature of 56°C for 30 minutes is practiced. Other treatments include methyl bromide fumigation and irradiation.

Paper-based packages

Fibreboard boxes or carton boxes have traditionally been used for the packaging of fruits and vegetables for export but are increasingly used for domestic distribution and marketing. Aside from their smooth surfaces, which are excellent for product protection, carton boxes are easily printable, are lightweight, amenable to modification (which facilitates protection of produce, e.g. cellular dividers, tray packing), and

Figure VII.3.1. Some wooden packages suitable for fruit and vegetable packaging

Source: K. Tanprasert

Figure VII.3.2. Standard wooden pallets for unitized handling of fruit and vegetable packages

Source: K. Tanprasert

have a clean and attractive appeal. Figure VII.3.3 shows some examples of fibreboard boxes including bulk bins used for packaging fruits and vegetables. The size of these boxes follows two common footprints (CF): CF1 = 60 x 40 cm and CF2 = 30 x 40 cm, having interlocking tabs and of unlimited height (Figure VII.3.3).

Boxes can be made of either solid or corrugated fibreboard, the latter being commonly used because they absorb shock better than the former. Corrugated fibreboard is made of linerboard and medium or corrugated board (Figure VII.3.4). Boxes that consist of only one linerboard and one corrugated board are referred to as single-faced; whereas those that consist of two linerboards and one corrugated board, are referred to as single-walled. Boxes may also be made of double-walled or triple-walled fibreboard.

Boxes are usually collapsible and may be telescopic (full or partial telescopic box) or slotted (regular or half slotted box) (Figure VII.3.4). Increasing the number of walls also increases box strength. Telescopic boxes are stronger than are slotted boxes.

Fibreboard does not provide good ventilation. Holes must, therefore, be incorporated into the side panel of fibreboard boxes in order to prevent the build up of heat and gases that can be detrimental to produce quality. Ventilation holes can, however, reduce compression strength. As a general rule, holes that occupy 5 percent of the sides of the box should be incorporated into boxes for produce that must be pre-cooled by forced air cooling.

Figure VII.3.3. Examples of fibreboard boxes

Source: KMUTT, 2007.

Plastic-based packages

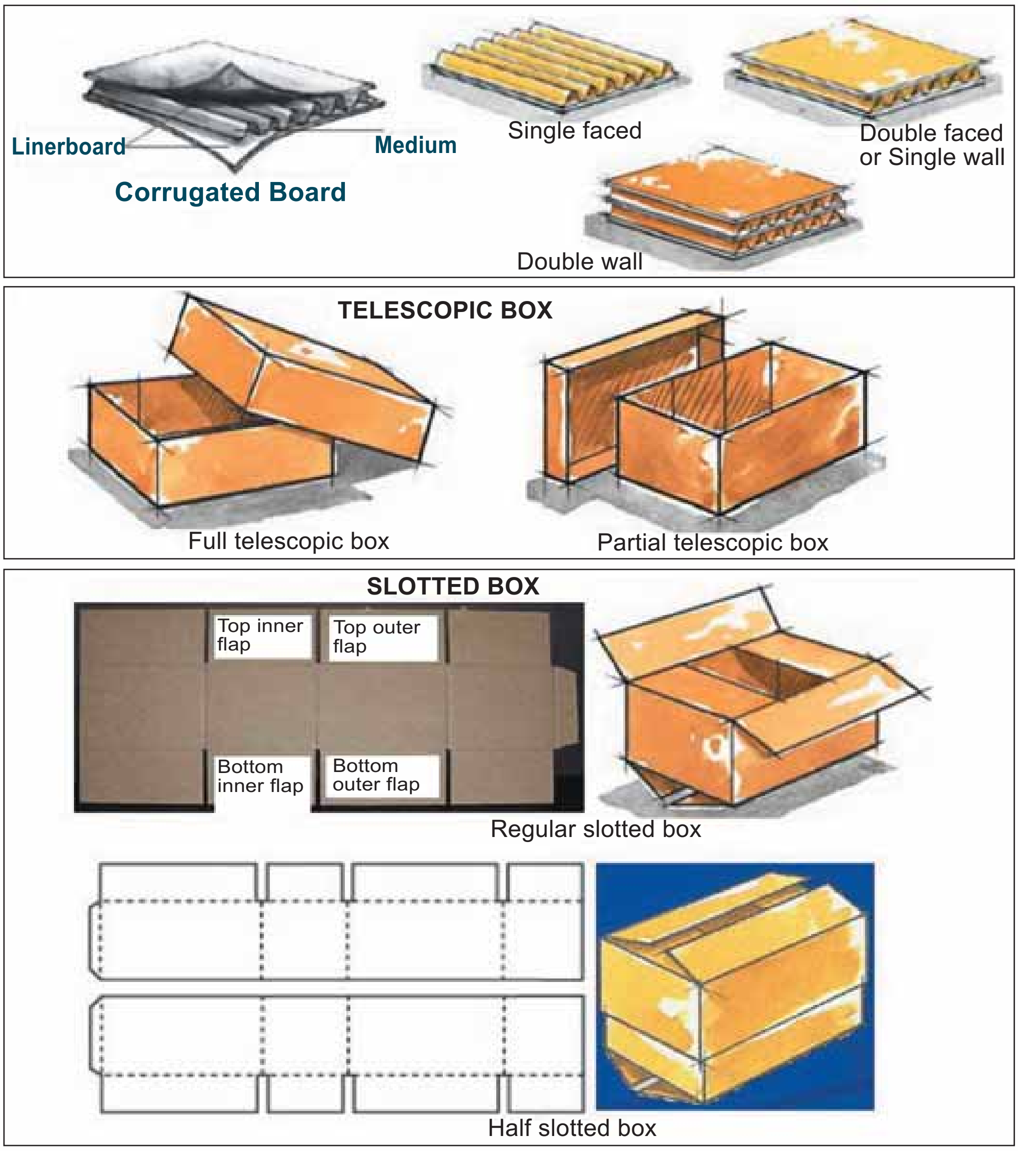
Plastic-based packages and packing materials include baskets, crates (that can be collapsible when empty), bags/pouches, clamshells, foam trays and foam nets (Figure VII.3.5). They are advantageous in use given that they are relatively thin, and of low density thereby reducing space requirements and transport cost. Plastic containers used for the packaging of fresh produce are generally made from polyethylene terephthalate (PETE), high density polyethylene (HDPE), low density polyethylene (LDPE), polyvinyl chloride (PVC), polypropylene (PP), polystyrene (PS), and other resins with international codes given in Figure VII.3.5.

Packing methods

Fresh produce is generally transferred to different types of packages (farm packages, bulk packages, display packages and retail packages) as it moves through the supply chain. The method of packing is critical to avoiding produce damage. Some packing methods are shown in Figure VII.3.6. These include:

- *Jumble packing* – This has a low packing density. Product movement can occur during transit, necessitating that the package be shaken during and after packing.
- *Pattern packing* – This is suitable for produce that is uniform in size. Produce is separated using dividers and trays can be used at the bottom layer of the package. The packing process is, however, slow.
- *Tray packing* – This makes use of trays under each layer of produce. The trays fit snugly under the package. This packing method reduces movement, distributes weight within the package, and therefore, helps in preventing mechanical injury. The packing process is slow.
- *Retail packing* – This is done for display purposes, with each pack having very low density. Retail packaging limits movement of the produce.

Figure VII.3.4. Nature of corrugated fibreboard, telescopic and slotted boxes



Source: KMUTT, 2007.

Figure VII.3.5. Plastic-based packages and packing materials for fruits and vegetables and international coding of plastic resins used in the production of packaging material

Plastic basket Plastic crates

Clamshell Foam net

Foam tray Plastic pouch

SPI Plastic Resin Coding

Code		Material
1	PETE	Polyethylene Terephthalate (PETTM)
2	HDPE	High Density Polyethylene
3	V	Polyvinyl Chloride (Vinyl or PVC)
4	LDPE	Low Density Polyethylene
5	PP	Polypropylene
6	PS	Polystyrene
7	OTHER	Other Resins

Source: KMUTT, 2007.

Figure VII.3.6. Methods of packing fruits and vegetables

Jumble pack

Pattern pack

Retail pack Tray pack

Source: KMUTT, 2007.

Careful handling is necessary during packing to avoid mechanical injury. Packers should also observe good hygienic practice to prevent contamination of produce with food-borne pathogens. Moreover, timely packing ensures efficient movement of produce through the supply chain.

Designing packages based on function

Protection

Tray packing, bubble wrapping, foam nets and liners are often used in order to protect produce from shock and vibration within the package. Soft material is more effective in limiting the movement of produce. Where produce is sensitive to compression, the package should bear the load rather than the produce. Containers should be of suitable compression strength.

Utility

Containment and space utilization – The package should be suitable sized for the produce that it contains.

Shelf life extension – Packaging technologies that can prolong produce shelf life include modified atmosphere packaging (MAP) and active packaging.

MAP is an inexpensive technique involving the use of polymeric films to create a low oxygen and high carbon dioxide atmosphere within the package in order to reduce physiological changes and quality loss. It works on the same principle as controlled atmosphere, but the latter offers more precise control of atmospheric gases and is much more costly in use. Optimum levels of oxygen and carbon dioxide that most benefit produce shelf life must be known. MAP systems must be carefully designed and extensively tested before application.

When produce is stored in MAP films, the atmosphere within the package continuously changes owing to the uptake of oxygen for produce respiration and the release of carbon dioxide as a respiratory product, until a steady state is attained, wherein oxygen and carbon dioxide levels are optimal. The time required to attain a steady state inside a MAP film, can be shortened either by increasing the volume of produce, decreasing the headspace volume within the package, or by increasing the thickness of the film. Conversely, reducing produce volume, increasing headspace volume and/or using thinner films can be employed to increase the oxygen level and reduce the carbon dioxide level within the package. Temperature is also critical in MAP systems since high temperatures increase produce respiration and gas permeation. MAP is therefore better employed as a component within a cold chain.

Active packaging also involves the use of polymeric films that incorporate treatments designed to reduce the time to reach a steady state (e.g. use of oxygen scrubber), avoid undesirable atmospheres (e.g. use of carbon dioxide and/or ethylene scrubbers), or help preserve quality and extend shelf life (e.g. 1-methylcyclopropene or MCP gas, which inhibits ethylene, a gaseous chemical that inhibits microbial decay and contaminants). Examples of oxygen scrubbers (other terms: absorber, scavenger) include iron powder, ascorbic acid, photosensitive dye, enzyme systems (e.g. glucose oxidase/catalase, alcohol oxidase), ferrous salts and unsaturated fatty acids. Lime and potassium permanganate, which are low-cost materials, can be used to remove carbon dioxide and ethylene, respectively in packages. These absorbers can be incorporated in sachets, labels or closure liners, or can be impregnated into the MAP film.

Environmental safety – Packages should have as little impact on the environment as possible as they enter the waste stream. They should therefore be designed to comply with the “reduce-reuse-recycle” concept of preserving the environment. Reusable or returnable packages reduce waste but additional costs are required for returning and cleaning the containers. Such packages are also costly. Research is continuing on the development of biodegradable packages.

Communication

In both domestic and export markets, retailers require reliable systems for identifying and tracing produce for stock control and as part of a quality assurance system. Information on the package may include cultivar, class type or size, weight or count, producer code, packing house code, name and address of supplier or exporter, country of origin, special treatments (e.g. wax, fungicide), and recommended storage and handling. Optional information may include trademark, certification mark, barcode, and environmental-related marking, which may be implicitly provided through colour, symbol, picture or texture. Other information may relate to produce quality and safety. Thus, packages should be designed to facilitate labelling for traceability and marketing purposes.

Bibliography

KMUTT. 2007. *Post-harvest: a technology for living produce*. Multimedia produced by the Division of Post-harvest Technology, King Mongkut's University of Technology Thonburi (KMUTT), Bangkok, Thailand.

Suggested methods of instruction

Lecture using handouts or visuals and discussion.

Practical exercises

Practical exercise VI.1: Impact of handling.

Time frame

1.5 hours for the lecture.
2 hours for the practical exercise.