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From field to market

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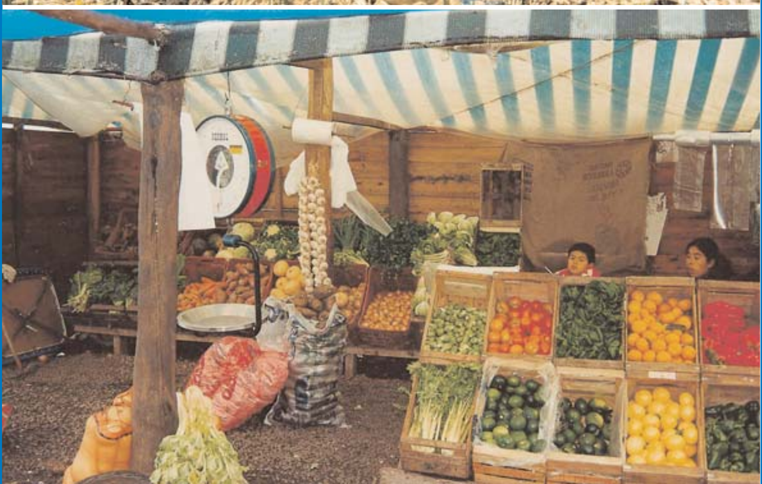

Food and Agriculture Organization of the United Nations

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by
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Preface

The production of fruits and vegetables in developing countries has considerably increased in recent years. However, an optimal use of these resources depends not only on the production increase in itself, but also on the improvement, in parallel, of associated infrastructure and postharvest operations of the produce, before it reaches the final consumer.

Value-adding technological and socio-economic aspects, such as employment generation and quality and safety of the final product, are critical for the efficient performance of the fruit and vegetable system.

Since trade in fruits and vegetables has reached record levels in both developed and developing countries for socio-economic, nutritional and cultural reasons among others, technological alternatives to facilitate and stimulate the development of the marketing of fruits and vegetables are required. This Manual for the preparation and sale of fruits and vegetables presents and clearly explains the main aspects to be taken into account when undertaking a commercial activity involving fruits and vegetables.

The manual contains basic and useful elements, with practical examples related to the harvesting, postharvest handling and marketing of fresh produce for the market including quality and safety aspects and produce storage. The annex includes formats of applicable regulations, based on the Codex Alimentarius, to ensure the quality and safety of the produce. In addition a glossary is provided allowing for the identification of a great variety of fruits and vegetables with large commercial potential.

Even though this manual adopts an approach based on the Latin American and the Caribbean experience, it can be used as a guide in any region or country where this experience is applicable.

Acknowledgements

I would like to thank FAO for having given me the opportunity to share my 30 years of experience in production, research and teaching on the vast, difficult and changing topic of the production and marketing of fruits and vegetables. I would like to especially acknowledge Danilo J. Mejía, Officer of the Agricultural and Food Engineering Technologies Service, FAO, Rome, not only for having proposed the programme to be developed but also for his valuable contributions and suggestions that helped to improve and enrich this work. Special thanks to Edward Seidler, Senior Officer (Marketing) of the Management, Marketing and Rural Finance Service, FAO, Rome, who edited the English translation of the publication, originally prepared in Spanish.

All photographs are by the author unless otherwise indicated.

Introduction

According to FAO estimates, in the year 2000 the population of Latin America and the Caribbean was around 518 million, which represented around 8 percent of the world's population. Approximately 80 percent of the population of the region lived in urban areas and 108 million farmers were responsible for meeting the food needs of the region. Estimates of fruit and vegetable production for the same year were around 32 and 93 million tonnes, respectively, representing 5 and 20 percent, respectively, of total world production. The fruit and vegetable sector is fragmented and comprises a large number of small-scale farmers. This group, including home gardeners, grow food for subsistence and do not figure in official statistics. The statistics highlighted above show the socio-economic importance of the agricultural sector.

Modernization in food production and supply systems has led to increased concentration in the food supply chain in many countries, with the rapid rise of supermarkets. The main beneficiaries have adapted by acquiring managerial skills, adopting new technology and making the necessary investments. This process has been gradual and has had an impact on many small-scale farmers. It has led to the current situation whereby high- and low-cost technology (or traditional) farming systems coexist. Suppliers in many current food distribution systems use high technology. On the other hand, there has been increased poverty and marginalization of many small-scale farmers.

Because large-scale farmers have easier access to technology, this manual focuses on small- and medium-scale farmers. It is hoped that it will help them to achieve: increased productivity; efficient use of limited resources available; lower production costs; reduced postharvest losses; increased competitiveness by adding value to production; and, more control over the final price.

In order to increase competitiveness, one of the main contributions and recurrent themes in this manual is the need for quality control. This is examined within the overall context of total quality management. In other words, a system of continuous improvement to satisfy the needs of consumers, well beyond their expectations. The underlying concept of this approach is that a quality product is achieved well before the seed is sown. However, for the purposes of this manual, harvesting is used as a starting point. It is based on the assumption that growing conditions are ideal for the crop.

In Chapter 1, harvest indexes are presented together with the handling conditions required to maintain quality.

Chapter 2 is mainly concerned with preparations for the fresh market within a packinghouse environment. This is a key step to adding value while at the same time protecting the product. Since all harvested produce is not sold immediately, storage is an integral part of the handling process. Some of its benefits include extending the growing season and minimizing losses in quality.

An examination of the different types of storage systems including their advantages and disadvantages is undertaken in Chapter 3.

Chapter 4 examines the health and safety issues related to handling produce from the field to the consumer.

Quality issues concerning the consumer are discussed in Chapter 5.

Chapter 6 focuses on alternative systems of retailing fruits and vegetables that are most appropriate for the small-scale commercial farmer.

A glossary is provided because of the differences in terminology for fruits and vegetables in Latin America and Caribbean countries. The Spanish and English names are given together with the scientific name. Key topics are illustrated with photographs from different growing areas in the world, with particular attention to Latin America and the Caribbean. The tables and graphics presented help to describe and highlight the issues further.

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Chapter 1

Harvest

1.1 Harvest systems

Harvesting is the gathering of plant parts that are of commercial interest. These include, for example, the following: *fruits* – tomatoes, peppers, apples, kiwifruits; *root crops* – beets and carrots; *leafy vegetables* – spinach and Swiss chard; *bulbs* – onions and garlic; *tubers* – potatoes; *stems* – asparagus; *petioles* – celery; and, i*nflorescences* – broccoli and cauliflower. Harvest marks the end of the growing period and the commencement of market preparation or conditioning for fresh products.

Harvesting can be performed by hand or mechanically. However, for some crops, such as onions, potatoes and carrots, it is possible to use a combination of both systems. In such cases, the mechanical loosening of soil facilitates hand harvesting. The choice of one or other harvest system depends on the type of crop, destination and acreage to be harvested. Fruits and vegetables for the fresh market are hand harvested while vegetables for processing or other crops grown on a large scale are mainly harvested mechanically.

The main advantages of mechanized harvesting are speed and the reduced costs per tonne harvested. However, because of the risk of mechanical damage, this system can only be used on crops that require a single harvest. A decision to purchase the necessary equipment calls for careful evaluation of the initial investment required as well as the maintenance costs. The long period in which equipment may have to stand idle should also be taken into consideration. In addition, the entire operation should be designed specifically for mechanized harvesting. Market preparation (grading, cleaning, packing, etc.) and trade systems should be set up to handle large volumes of produce.

Hand harvesting is particularly suitable for crops with an extended harvest period. The rate of harvesting can be increased by hiring more workers if, for example, ripening is accelerated because of climatic conditions and the crop must be harvested quickly. The main benefit of hand harvesting compared with mechanized harvesting is that humans are able to select the produce at its correct stage of ripening and handle it carefully. The result is a higher quality product with minimum damage. This is important for tender crops. Adequate training, including supervision of the harvest crew, is required. In Figure 1, apples harvested by an unsupervised crew had more bruises than those harvested when close supervision was available.

Contractual arrangements with the labour force also influence the quality of produce. When wages are paid on a weekly, fortnightly or monthly basis, harvesting is usually undertaken carefully. On the other hand, when payment is based on the number of boxes, metres of row or plants harvested, handling can become careless. The establishment of teams and division of labour also influence the quality of produce. Long working days and/or few breaks as well as extremely adverse conditions (excessive heat or cold) can result in unnecessary rough handling of produce. The harvest labour force must be adequately trained to select produce at the correct stage of ripeness or degree of maturity. They must also learn sorting techniques in order to minimize damage.

1.2 Harvest ripeness and readiness for harvest

In many cases harvest ripeness and readiness for harvest are used synonymously. However, it is more technically accurate to use “ripeness” for fruits such as tomatoes, peaches and peppers. For these fruits the consumption stage continues after certain changes in colour, texture and flavour. On the other hand, for crops where these changes do not occur, for example, asparagus, lettuce and beets, the term “readiness for harvest” is preferable.

Maturity is the harvest index most widely used in fruits. However, *physiological maturity* needs to be distinguished from *commercial maturity*. The former is reached when development is over. It may or may not be followed by the ripening process to achieve the commercial maturity required by the market. Every fruit shows one or more apparent signs when it reaches physiological maturity. For example, in tomatoes the gelatinous mass fills the internal locules and seeds cannot be cut when fruits are sectioned with a sharp knife. In peppers the seeds become hard and the internal surface of the fruit starts colouring (Figure 2).

Overmaturity or overripening is the stage that follows commercial maturity and occurs when the fruit softens and loses part of its characteristic taste and flavour. It is the ideal condition for preparing jams or sauces (Figure 3). Commercial maturity may or may not coincide with physiological maturity. For cucumbers, zucchinis, snap beans, peas, baby vegetables and many others, commercial maturity is reached well before the end of

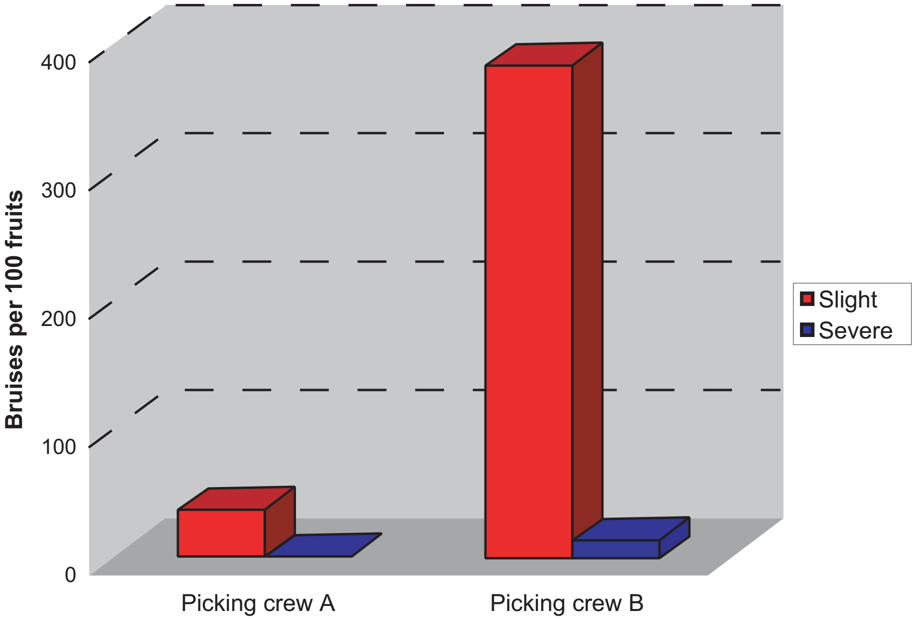

Figure 1: **Number of slight and severe bruises per 100 apples according to the degree of supervision. Picking crew A is closely supervised; picking crew B is not supervised. (adapted from Smith *et al.,* 1949).**

development.

At this point, it is necessary to differentiate between two types of fruits: climacteric and non-climacteric. Climacteric fruits such as tomatoes and peaches are capable of generating ethylene, the hormone required for ripening even when detached from the mother plant. Non-climacteric fruits such as peppers and citrus obtain commercial maturity only on the plant (Table 1). Climacteric fruits are autonomous from the ripening point of view and changes in taste, aroma, colour and texture are associated with a transitory respiratory peak and closely related to autocatalytic ethylene production. Figures 4 and 5 illustrate this point: climacteric fruits such as tomatoes reach full red colour even when harvested green (Figure 4, left). On the other hand, in non-climacteric fruits, such as bell peppers, slight changes in colour take place after harvest. Full red colour is only obtained while fruit is attached to the plant (Figure 5). As a general rule, the more mature the product, the shorter its postharvest life. Climacteric fruits need to be harvested as early as possible for distant markets, but always after reaching their physiological maturity.

Figure 2: **Physiological maturity in the bell pepper is reached when seeds become hard and the internal cavity starts colouring.**

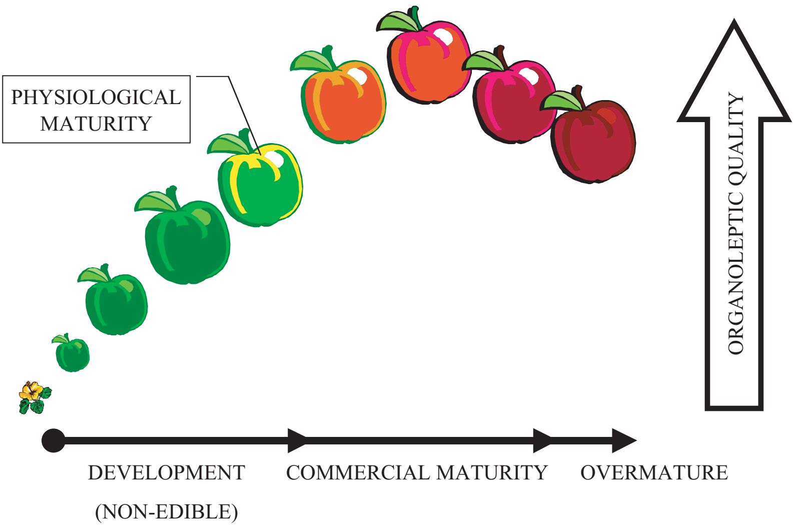

Figure 3: **Organoleptic quality of a fruit in relationship to its ripening stage.**

Table 1: **Climacteric and non-climacteric fruits**

Non-climacteric		Climacteric	
Bell pepper	Olives	Apple	Melons
Blackberries	Orange	Apricot	Nectarine
Blueberries	Pineapple	Avocado	Papaya
Cacao	Pomegranate	Banana	Passionfruit
Cashew apple	Pumpkin	Breadfruit	Peach
Cherry	Raspberries	Cherimoya	Pear
Cucumber	Strawberries	Feijoa	Persimmon
Eggplant	Summer squash	Fig	Plantain
Grape	Tart cherries	Guanábana	Plum
Grapefruit	Tree tomato	Guava	Quince
Lemon		Jackfruit	Sapodilla
Lime		Kiwifruit	Sapote
Loquat		Mamey	Tomato
Lychee		Mango	Watermelon

Source: Wills, *et al.,* 1982; Kader, 1985

Changes in colour are the most apparent external symptoms of ripening. They are the result of chlorophyll degradation (disappearance of green colour) and the synthesis of specific pigments. In some fruits such as lemons, chlorophyll degradation allows yellow pigments that are already present to show; however, these are masked by the green colour. Other fruits, such as peaches, nectarines and some varieties of apples, have more of one type of colour – the ground one is associated with ripeness and the cover in many cases is specific to the variety (Figure 6). Maturity can be estimated by colour charts based on the percentage of desired colour (Figures 4 and 5) or by objective measurements with colorimeters (Figure 7).

Degree of development is the harvest index most widely used in vegetables and some fruits, in particular those harvested before maturity. Soybean, alfalfa and other legume sprouts are harvested before expansion of the cotyledon. Asparagus are gathered when the stems emerging from soil reach a certain length. Haricot beans and other snap beans are harvested when they reach a certain diameter (Figure 8); and snow peas and other legumes before seed development becomes evident (Figure 9). The harvesting of let-

Figure 4: **Degree of ripening in tomato (from left to right): 1) mature green; 2) breaker; 3) turning; 4) pink; 5) light red; and 6) red. Because of its climacteric ripening characteristics, the tomato reaches stage 6 even when harvested at stage 1.**

tuce, cabbage and other "head" forming vegetables is based on compactness while "shoulder" width is used in beets, carrots and other roots. Plant size as a harvest index is used in many vegetables such as spinach. However, in the case of potatoes (Figure 10), sweet potatoes and other root vegetables, readiness for harvest is based on the percentage of tubers of a specific size.

Many crops show apparent external symptoms when ready for harvest. These include, for example, onion tops falling over (Figure 11), the development of abscission layers in the pedicel of some melons, hardness of the epidermis of certain pumpkins and shell fragility in some nuts. Degree of filling is an index used in bananas and mangoes while sweet corn is harvested when kernels are plump and no longer "milky".

The main criteria used for harvesting most fruits and vegetables are colour and the degree of development, or both. It is, however, common to combine these with other objective indices. These include, for example, firmness (apple, pear, stone fruits) (Figure 12), tenderness (peas), starch content (apple, pear) (Figure 13), soluble solid content (melons, kiwifruit), oil content (avocado), juiciness (citrus), sugar content/acidity ratio (citrus), aroma (some melons). For processing crops, it is important to keep a constant flow of raw material in the harvesting schedule. It is therefore normal practice to calculate the number of days from flowering and/or the accumulation of heat units.

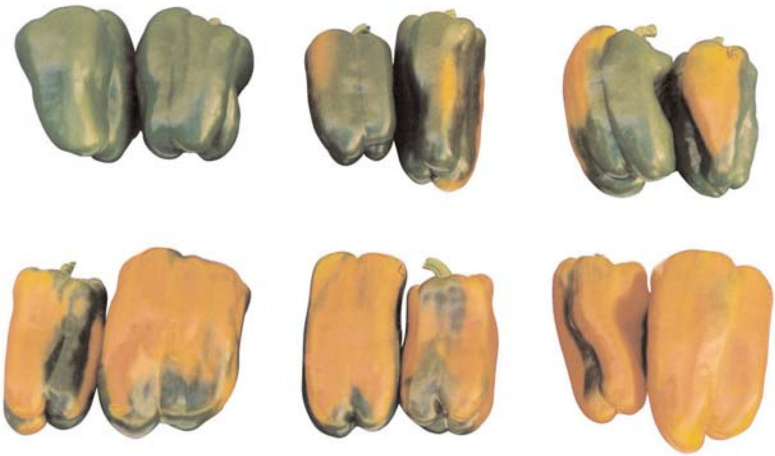

Figure 5: **Degree of ripening in bell pepper. As with other non-climacteric fruits, ripening does not follow after harvest.**

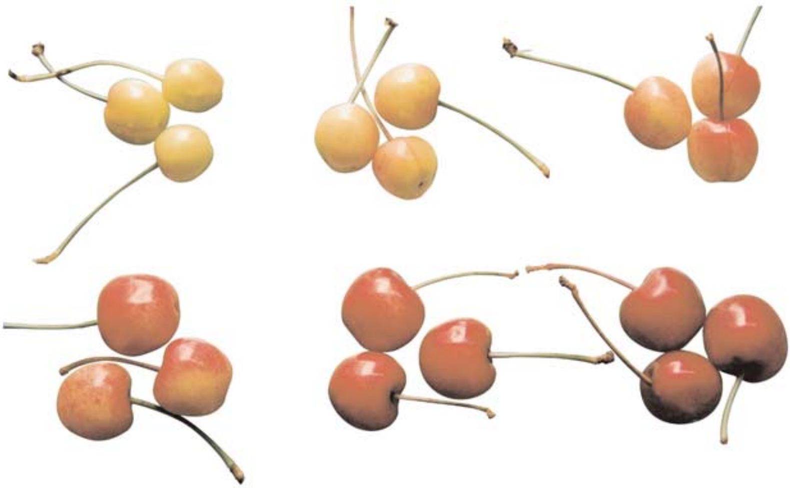

Figure 6: **Some cherry varieties have a ground colour that changes when fruit reaches maximum development (photograph: A. Yommi, INTA E.E.A. Balcarce).**

Figure 7: **Objective colour measurement with a colorimeter.**

Figure 8: **Harvest maturity based on the bean diameter.**

Figure 9: **Readiness for harvest based on the degree of seed development.**

Figure 10: **Readiness for harvest based on the percentage of tubers of the desired size.**

Figure 11: **Tops bending and falling over indicate that onions are ready for harvest.**

Figure 12: **Objective firmness measurement.**

Figure 13: **Starch stains darken when fruit cross sections are dipped in an iodine solution. Percentage of starch disappearance can be used as a maturity index in apples (reproduced from Ctifl, 1993).**

1.3 Handling during harvest

Harvesting involves a number of other activities undertaken in the field including those of commercial interest. Examples of operations to facilitate preparation for the market include pre-sorting and the removal of foliage and other non-edible parts. In some cases, the product is completely prepared for the market in the field. The normal practice however is to empty the harvest containers into larger ones for transportation to the packinghouse (Figure 14) where they are dry- or water-dumped onto grading lines. Most bruising occurs while these activities are being undertaken. It has a cumulative impact that can affect the final quality of the produce (Figure 15).

Different types of lesions exist. Wounds (cuts and punctures) occur as a result of loss of tissue integrity. This type of damage is frequent during harvest and mainly produced by the harvesting tools used for the removal of plants. Other causes include the fingernails of pickers or peduncles from other fruits (Figure 16). Rotting fungi and bacteria penetrate produce in this way. This type of damage can be easily detected and the affected produce is usually removed during grading and packing. Bruises are more common than wounds. They are less noticeable and symptoms show up several days later when the product is in the hands of the consumer. There are three main causes of bruises:

1. *Impact:* Injury caused either by dropping the fruit (or packed fruits) onto a hard surface or by the impact of fruit rubbing against other fruit. These types of bruises are common during harvest and packing (Figure 17).
2. *Compression*: Deformation under pressure often occurs during storage and bulk transportation and is caused by the weight of the mass of fruits on bottom layers. It also happens when the packed mass exceeds the volume of the container (Figure 18) or when weak boxes or packages cannot withstand the weight of those piled up high.
3. *Abrasion*: Superficial damage produced by any type of friction (other fruits, packaging materials, packing belts, etc.) against thin-skinned fruit like pears. Abrasions on onions and garlic result in the loss of protective scales (Figure 19).

Bruise symptoms depend on the affected tissue, maturity, type and severity of the bruise. They are cumulative and in addition to their traumatic effect, trigger a series of responses to stress, including the onset of healing mechanisms. This physiological reaction is as follows: a temporary increase in respiration, which is associated with degradation; a transient production of ethylene, which accelerates maturation and contributes to softening. In some cases, mechanical disruption of membranes puts enzymes in contact with substrates, which leads to the synthesis of secondary compounds that may affect texture, taste, appearance, aroma or nutritive value. Firmness on the site of impact decreases rapidly because of damage and cell death as well as the loss of tissue integrity. The more mature the product, the more severe the damage. Its effect is exacerbated by higher temperatures and longer storage periods. Ethylene removal or neutralization under controlled or modified atmosphere conditions reduces the speed of healing. However, atmospheric composition also reduces the rate of stress response mechanisms.

Figure 14: **Harvested fruits ready to be transported to the packinghouse.**

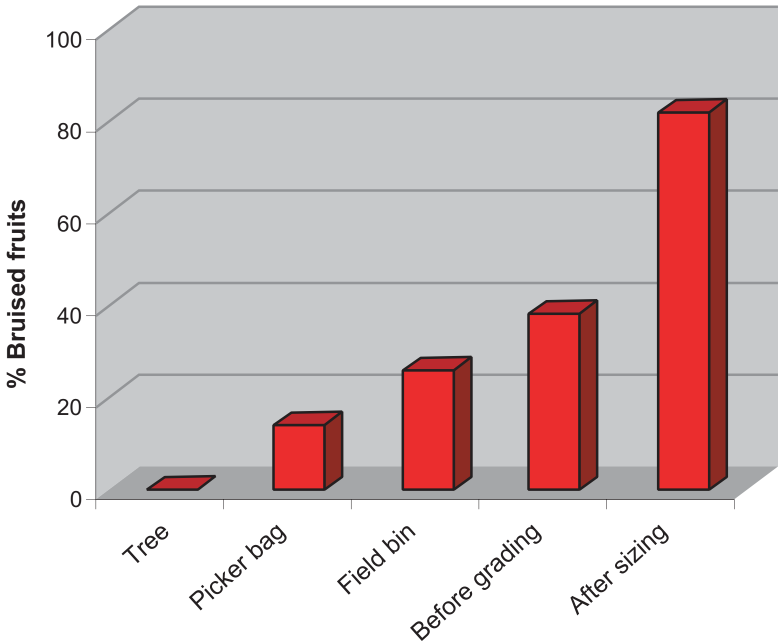

Figure 15: **Cumulative impact of bruises on Bartlett pears during postharvest handling (adapted from Mitchel, 1985).**

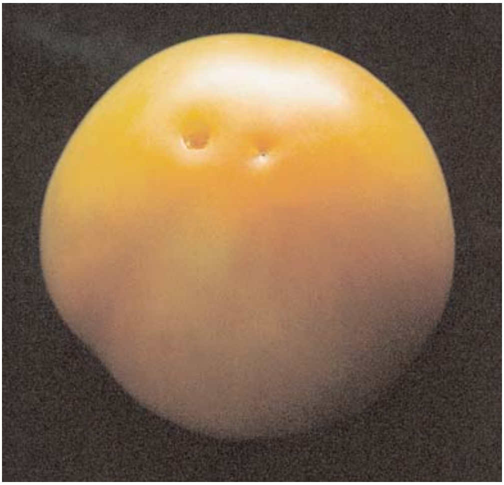

Figure 16: **Injury caused by the peduncle of other fruit during transport.**

Figure 17: **Impact bruise on pear.**

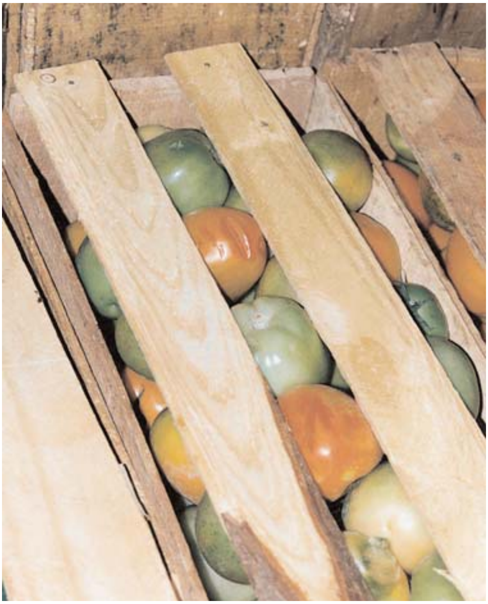

Figure 18: **Compression injuries on tomatoes.**

Figure 19: **Abrasions on onion bulbs result in the loss of protective scales.**

1.4 Harvest recommendations

- If the time of day can be selected, it is recommended to harvest during the cool morning hours when products are more turgid. Furthermore, less energy is required for refrigeration.
- Harvesting maturity is a function of the distance to the destination market: those within close proximity allow ripening on the plant.
- Harvested produce must be kept in the shade until the time of transportation.
- Avoid product bruising. Scissors or knives used for harvesting should have rounded ends to prevent punctures and be sharp enough to prevent tearing off. Harvest containers should be cushioned, smooth and free of sharp edges. Do not overfill field containers and move them carefully (Figure 20). Minimize drop heights when transferring produce to other containers.
- Train harvest labourers to handle produce gently and to identify correct maturity for harvest. Wear gloves during harvesting and handling to avoid damage to fruits.

Figure 20: **Foliage can be used for cushioning and protecting cauliflower during transportation.**

1.5 Curing

Curing complements harvesting in certain crops and is needed to achieve a quality product. It is a process involving rapid loss of superficial humidity. In addition to developing some tissue changes, it prevents further dehydration. It also acts as a barrier against the penetration of pathogens. For onions and garlic curing is the drying of external scales together with colour development and neck closure. For root crops (sweet potatoes and yams) and tubers (potatoes), skin hardening prevents skinning during harvesting and handling and the development of the healing periderma on wounds (suberization). For pumpkins and other cucurbits, curing is the hardening of the skin, while in citrus it is the natural formation of a layer of lignified cells. This prevents the formation and development of pathogens.

Curing is normally undertaken in the field. Garlic and onions are cured by undercutting and windrowing plants to protect them from direct sun or by putting them in heaps or burlap bags (Figure 21) for a week or more. Potatoes must remain in the soil for 10 to 15 days after foliage is destroyed with herbicides. Sweet potatoes and other roots are cured in a similar way although curing is normally carried out under shelters. If required, curing may be performed artificially in storage facilities by forced circulation of hot and humid air (Table 2). After curing, temperature and relative humidity conditions are set for long-term storage.

Figure 21: **Curing onion bulbs in burlap sacks.**

Table 2: **Recommended temperature and relative humidity conditions for curing**

	Temperature (°C)	Relative humidity (%)
Potato	15-20	85-90
Sweet potato	30-32	85-90
Yam	32-40	90-100
Cassava	30-40	90-95
Onion & garlic	33-45	60-75

Chapter 2

Preparation for the fresh market

2.1 The need for a packinghouse

After harvest, fruits and vegetables need to be prepared for sale. This can be undertaken on the farm or at the level of retail, wholesale or supermarket chain. Regardless of the destination, preparation for the fresh market comprises four basic key operations:

1. removal of unmarketable material
2. sorting by maturity and/or size
3. grading
4. packaging

Any working arrangement that reduces handling will lead to lower costs and will assist in reducing quality losses. Market preparation is therefore preferably carried out in the field. However, this is only really possible with tender or perishable products or small volumes for nearby markets. Products need to be transported to a packinghouse or packing shed for large operations, for distant or demanding markets or for special operations like washing, brushing, waxing, controlled ripening, refrigeration, storage or any specific type of treatment or packaging.

These two systems (field vs packinghouse preparation) are not mutually exclusive. In many cases partial field preparation is completed later in the packing shed. Because it is a waste of time and money to handle unmarketable units, primary selection of fruits and vegetables is always carried out in the field where products with severe defects, injuries or diseases are removed.

Field preparation of lettuce is an example where a team of three workers cut, prepare and pack (Figure 22). For distant markets, boxes prepared in the field are delivered to packinghouses for palletizing, precooling, and sometimes cold storage before shipping. Mobile packing sheds provide an alternative for handling large volumes in limited time. Harvest crews feed a mobile grading and packing line (Figure 23). On completion of loading, the consignment is shipped to the destination market. In mechanized harvesting, the product is transported to the packinghouse (Figure 24) where it is prepared for

Figure 22: **Field preparation of lettuce for the fresh market.**

Figura 23: **Mobile packing shed for market preparation of celery.**

Figure 24: **Mechanized harvesting of tomatoes.**

the market. In many cases, harvest crews make use of an inspection line for primary selection in the field.

2.2 The packinghouse

A packinghouse allows for special operations to be performed. One of the main advantages is that products can be prepared continuously for 24 hours regardless of the weather. Because of its capacity to process large volumes, a packinghouse can be used by farmers associations, cooperatives, or even community organizations.

The size and degree of complexity of a packing shed should be based on crop(s) and volume to be processed, capital to be invested and objectives such as handling of owner's production or providing service to others. Packing sheds range from a straw shelter to highly automated facilities. In some cases storage rooms as well as offices for commercial sales are annexed to packing sheds.

A packinghouse can be defined as a place protected from weather for both produce and personnel. It is organized in such a way that the produce is prepared in a centralized handling operation. To some extent, this is similar to a factory assembly line, where raw material from the field undergoes a sequence of activities resulting in the final packaged product.

2.2.1 General considerations about design

A packinghouse needs to be located close to the production area and within easy access to main roads or highways. It should have one entrance to facilitate and control supply and delivery. Moreover, it needs to be large enough for future expansion or additional new facilities. Sufficient space outside is also required to avoid congestion of vehicles entering and leaving. Packinghouses should be designed to ensure sufficient shade during most of the day in the loading and unloading areas. Buildings need good ventilation in summer and protection in winter.

Packinghouses are usually built with cheap materials. However, it is important to create a comfortable environment for both produce and labour force. Produce exposed to unfavourable conditions can lead to rapid deterioration in quality. Also, uncomfortable working conditions can lead to unnecessary rough handling.

A packinghouse should have adequate room for easy circulation with ramps to facilitate loading and unloading. Doors and spaces should be sufficiently large to allow for the use of forklifts. The reception area should be large enough to hold a sufficient amount of produce for one working day. The main reason for this is to keep the packinghouse in operation in the event of an interruption in the flow of produce from the field (rain, machine breakdown, etc).

Electricity is critical for equipment, refrigeration and particularly lighting. Because packinghouses usually operate for many hours or even continuously during harvest time, lighting (intensity and quality) is a key factor in identifying defects on inspection tables. Lights should be placed below eye level to prevent glare and eyestrain (Figure 25). Light intensity should be between 2 000 and 2 500 lx for light coloured products but between 4 000 and 5 000 lx for darker ones. It is important that the whole building has lighting, not only the working area, in order to avoid the contrasts caused by shaded areas, resulting in temporary blindness when the eyes are raised. Dull colours and non-glossy surfaces are a requirement for equipment, conveyor belts and outfits. In this way, defects are not masked because of the reflection of light and eye fatigue is reduced.

A good supply of water is important for washing produce, trucks, bins and equipment as well as for dumping. In some cases it may also be necessary for hydrocooling. Provision of an adequate wastewater disposal system is as important as a good source.

Administration offices should be located in clean and quiet areas and, if possible, elevated so that the entire operation is visible (Figure 26). Packinghouses should have facilities or laboratories for quality analysis.

After working out the details of the building layout, it is important to prepare a diagram for the movement of produce throughout the packinghouse and for all other activities. Handling must be minimized and movement of produce should always be in one direction without crossovers. It may be possible to undertake operations concurrently, for example, working simultaneously on different sizes or maturity stages.

2.2.2 General considerations about operations

2.2.2.1 Reception

Preparation and packing operations should be designed to minimize the time between harvest and delivery of the packaged product. Delays frequently occur in the reception area, therefore the produce should be protected from the sun as much as possible (Figure 27). Produce is normally weighed or counted before entering the plant and, in some cases, samples for quality analysis are taken (Figure 28). Records should be kept, particularly when providing a service to other producers.

Preparation for the fresh market starts with dumping onto packinghouse feeding lines. Dumping may be dry (Figure 29) or in water (Figure 30). In both cases it is important to have drop decelerators to minimize injury as well as to control the flow of produce. Water dipping produces less bruising and can be used to move free-floating fruits; however, not all products tolerate wetting. Products with a specific density lower than water

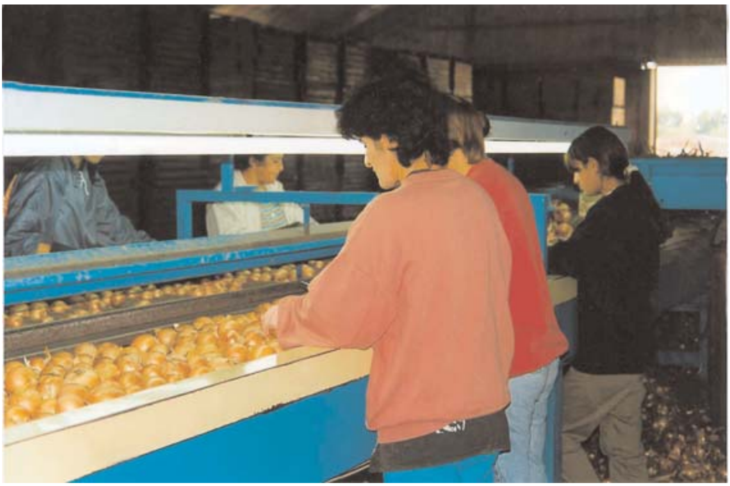

Figure 25: **Lighting at eye level causes blinding and eye fatigue. Lighting fixtures should also be covered to prevent glass shattering over produce if broken.**

Figure 26: **Elevated administration offices allow process supervision.**

will float. Salts (e.g. sodium sulphate) are diluted in the water to improve the flotation of other products.

Water dipping through washing helps to remove most dirt from the field. For thorough cleaning, more washing and brushing are required. Water rinsing allows produce to maintain cleanliness and be free of soil, pesticides, plant debris and rotting parts. However, in some cases this is not possible because of insufficient water. If recycled water is used, it needs to be filtered and the settled dirt removed.

Chlorination of dumping and washing waters with a concentration of 50-200 ppm active chlorine eliminates fungi spores and bacteria on the surface of diseased fruits, which prevents the contamination of healthy fruit. Bruising should be avoided because it creates the entry for infection by decay organisms. At depths greater than 30 cm and for periods of immersion longer than three minutes, water tends to penetrate inside fruits, particularly those that are hollow, for example, peppers. Water temperature also contributes to infiltration. It is recommended that the temperature of fruit is at least 5 °C lower than that of water.

Figure 27: **Delays should be avoided either at reception or delivery, particularly when produce is exposed to the sun.**

2.2.2.2 Removal of rejects

After dumping, the first operation that usually follows is the removal of unmarketable produce because the handling of plant material that cannot be sold is costly. This is performed prior to sizing and grading. Primary selection is one of the four basic operations for market preparation carried out in the field. This step involves the removal of produce that is overripe, too small, severely damaged, deformed or rotting.

Very small produce is usually removed mechanically by mesh screens, pre-sizing belts or chains. Bruised, rotted, off-shaped units and wilted or yellow leaves are usually removed by hand. Garlic and onions are topped to remove the dry foliage attached to the bulbs by specific equipment (Figure 31) and in many crops soil and loose parts are removed by brushing (Figure 32). For crops that tolerate water dipping, differential flotation is used to separate rejects and detergents, and brushes are used to remove soil, latex, insects, pesticides, etc. Clean fruits should be dried with sponges or hot air.

Bruised and spoiled fruits as well as culls and other plant parts from cutting, peeling and trimming can be used for animal feeding. Although this plant material provides a good source of energy and is extremely tasty, its high water content makes it bulky and expensive to transport. In addition, the nutritional value is less than that of other food

Figure 28: **Sampling for quality before grading.**

sources because of its low protein and dry matter content (in terms of volume). Inclusion in the diet of this plant material must be in the right proportions to avoid digestive problems. In many cases it is highly perishable and cannot be stored, which means that it cannot be gradually introduced into the animal's diet. When not used for animal feeding, it can be disposed of as sanitary fillings or organic soil amendments.

2.2.2.3 Sizing

Sizing is another basic operation undertaken in a packinghouse and can be carried out before or after sorting by colour. Both operations should always be carried out before grading because it is easier to identify units with defects on a uniform product, in terms of either size or colour.

There are two basic systems for sizing: according to weight and according to dimensions (diameter, length, or both). Spherical or almost spherical products such as grapefruits, oranges and onions are probably the easiest to sort by size. Several mechanisms are available from mesh screens to diverging belts (Figure 33) or rollers with increased spaces between them (Figure 34). Sizing can also be performed manually using rings of known diameter (Figure 35). For many crops sorting by weight is carried out with weight-sensitive trays that automatically move fruit onto another belt, aggregating all units of the same mass (Figure 36).

Figure 29: **Dry dumping of lemons (photograph: P. A. Gómez, INTA E.E.A. Balcarce).**

2.2.2.4 Grading

Amongst the four basic operations, grading is probably the most important. It consists of sorting produce in grades or categories of quality. Two main systems exist: static and dynamic. Static systems are commonly used for tender and/or high-value crops. The produce is placed on an inspection table where sorters remove units that do not meet the requirements for the grade or quality category (Figure 37). The dynamic system is probably much more common. The produce moves along a belt in front of the sorters who remove units with defects (Figure 38). Main flow is the highest quality grade. Often second- and third-grade quality units are removed and placed onto other belts. It is much more efficient in terms of volume sorted per unit of time. Personnel should be well trained because every unit remains only a few seconds in the worker's area of vision. Two common mistakes are removing good quality units from the main flow and, more frequently, not removing produce of doubtful quality.

Units rejected mainly on aesthetic grounds provide a second- or even third-quality grade that can be marketed in less demanding outlets or used as raw material for processing.

Figure 30: **Water dumping of apples.**

The standard of quality achieved by small-scale processing must be similar or even better than that achieved by large-scale industrial processing. This is not always possible because industrial plants tend to use specific varieties and processes. In addition, surpluses for the fresh market and substandard products do not provide uniform raw material. The industrial yield is low and this together with the low technology in the manufacturing process can result in a product of variable quality. At this point, it is important to highlight that the quality of a processed product depends on the quality of the raw material and the manufacturing process.

2.2.3 Special operations

Special operations are commodity specific. They are different from basic operations because they are carried out on every crop independent of the size and sophistication of the packinghouse.

2.2.3.1 Colour sorting

Colour sorting is commonly used for fruits and vegetables and can be undertaken electronically. Fruits are usually harvested within a range of maturity (Figure 39) that needs to be uniform for sale. Harvesting within a narrow range of maturity reduces colour sorting; however, it is only possible for low-volume operations.

Figure 31: **Topping onions before grading.**

2.2.3.2 Waxing

Some fruits, such as apples, cucumbers, citrus, peaches and nectarines, are waxed to reduce dehydration, to improve their postharvest life by replacing the natural waxes removed by washing, and to seal small wounds produced during handling. Waxes are also used as carriers for the application of some fungicides or just to increase shine and improve appearance. Different types and formulae of waxes are available. These can be applied as sprays or foams, by immersion and dripping or in other ways. Uniform distribution is important. Soft brushes, rollers or other methods are used to ensure that application on the surface of fruit is thorough and texture is even. Heavy application can block fruit gas exchange and produce tissue asphyxia. Internal darkening and the development of off-flavours and off-odours are some of the characteristics. It is very important that waxes are approved for human consumption.

2.2.3.3 Degreening

Citrus fruit in particular often reaches commercial maturity with traces of green colour on the epidermis (flavedo). Greening is caused mainly by the climatic conditions before harvest. Although not different from fruits with colour, consumers sense that they are not ripe enough and have not reached full flavour. Degreening consists in chlorophyll degradation to allow for the expression of natural pigments masked by the green colour. In purpose-built chambers, citrus fruits are exposed from 24 to 72 hours (depending on degree of greening) to an atmosphere containing ethylene (5-10 ppm) under controlled

Figure 32: **Brushing and hand removal of damaged fruits before grading (photograph: S. Horvitz, INTA E.E.A. Balcarce).**

Figure 33: **Sizing onion bulbs with diverging belts. The different speed of belts makes bulbs rotate besides moving forward to a point where bulb diameter equals belt separation.**

Figure 34: **Sizing using rollers with increased space between them.**

Figure 35: **Sizing with rings of known diameters (photograph: P. A. Gómez, INTA E.E.A. Balcarce).**

Figure 36: **Sizing by weight. Individual trays deposit fruit on the corresponding conveyor belt.**

Figure 37: **Static quality grading system. Product is dumped onto an inspection table where defective units are removed.**

ventilation and high relative humidity (90-95 percent). Conditions for degreening are specific to the production area. Artés Calero (2000) recommends temperatures ranging from 25 to 26 °C for oranges, 22 to 24 °C for grapefruit and lemons and 20 to 23 °C for mandarins.

2.2.3.4 Controlled ripening

Maturity at harvest is the key factor for quality and postharvest life. When shipped to distant markets, fruits must be harvested when slightly immature (particularly climacteric fruits) to reduce bruising and losses during transport. However, prior to distribution and retail sales it is necessary to speed up and achieve uniform ripening so that produce reaches consumers at the right stage of maturity. As with degreening, ethylene is used but at higher concentrations. This type of operation is used for bananas. It can also be used for tomatoes, melons, avocados, mangoes and other fruits (Table 3).

Controlled ripening is carried out in purpose-built rooms where temperature and relative humidity can be controlled and ethylene removed when the process has been completed. The process involves initial heating to reach the desired pulp temperature. This is followed by an injection of ethylene at the desired concentration. The product is maintained under these conditions for a certain amount of time followed by ventilation in order to remove accumulated gases. On completion of the treatment, the temperature is reduced to the desired level for transportation and/or storage. Ethylene concentration and exposure time are functions of temperature, which accelerates the process.

Table 3: **Conditions for controlled ripening of some fruits**

	Ethylene concentration (ppm)	**Ripening temperature °C**	**Exposure time to these conditions (hr.)**
Avocado	10-100	15-18	12-48
Banana	100-150	15-18	24
Honeydew melon	100-150	20-25	18-24
Kiwifruit	10-100	0-20	12-24
Mango	100-150	20-22	12-24
Stone fruits	10-100	13-25	12-72
Tomato	100-150	20-25	24-48

Adapted from Thompson, 1998.

Figure 38: **Dynamic quality grading system. Sized onion bulbs continuously flow on inspection tables where defective products are removed. Final inspection is performed before bagging (right-hand side).**

Figure 39: **Fruits are harvested within a range of maturity and should be separated by colours before packing. (photograph: S. Horvitz, INTA E.E.A. Balcarce).**

2.2.3.5 Pest and disease control

Different treatments are performed to prevent and control pests and diseases at postharvest level. Fungicides belonging to different chemical groups are widely used for citrus, apples, bananas, stone fruits and other fruits. Most have a fungistatic activity, which means that they inhibit or reduce germination of spores without complete suppression of the disease. Chlorine and sulphur dioxide are amongst those most widely used.

Chlorine is probably the most widely used sanitizer. It is used in concentrations ranging from 50 to 200 ppm in water to reduce the number of microorganisms present on the surface of the fruit. However, it does not stop the growth of a pathogen already established. Table grapes are usually fumigated with sulphur dioxide to control postharvest diseases at a concentration of 0.5 percent for 20 minutes followed by ventilation. During storage, the produce is fumigated periodically (every 7 to 10 days) in concentrations of 0.25 percent. During transport, pads impregnated with sodium metabisulphite can be used inside packages. These slowly generate sulphur dioxide in contact with the humidity released by fruits.

Gas fumigation has been the most important method for eliminating insects (adults, eggs, larvae or pupae). Methyl bromide was probably the most widely used fumigant for many years but it is now banned in most countries. It has been replaced by temperature treatment (high and low), controlled atmospheres and other fumigants or irradiation.

It is also possible to prevent some postharvest physiological disorders with chemical treatments, for example, calcium chloride (4 to 6 percent) dips or sprays for bitter pit in apples. Other methods include dipping or drenching fruits in chemical solutions to avoid storage scalds or other disorders. Similarly, the addition of low concentrations of 2.4-D to waxes helps to keep citrus peduncles green.

2.2.3.6 Temperature treatments

Cold treatments can be used in low-temperature-tolerant fruits (apples, pears, kiwifruit, table grapes, etc.) and other potential carriers of quarantine pests and/or their ovipositions. Recommended exposure of temperature and time combinations is provided in Table 4.

Heat treatments like hot water dips or exposure to hot air or vapour have been used for many years for insect control (and for fungi, in some cases). However, when restrictions were extended to bromine based fumigants, heat treatments were reconsidered as quarantine treatments in fruits and vegetables such as mangoes, papayas, citrus, bananas, carambola, peppers, eggplants, tomatoes, cucumbers and zucchinis. Temperature, exposure and application methods are commodity specific and must be carried out precisely in order to avoid heat injuries, particularly in highly perishable crops. On completion of treatment, it is important to reduce temperature to recommended levels for storage and/or transport.

For hot water immersion, fruit pulp temperature should be between 43 and 46.7 °C for 35 to 90 minutes. This depends on commodity, insect to be controlled and its degree of development (U.S. E.P.A., 1996). Dipping in hot water also contributes to reduced microbial load in plums, peaches, papaya, cantaloupes, sweet potatoes and tomatoes (Kitinoja and Kader, 1996) but does not always guarantee good insect control (U.S. E.P.A., 1996). For the export of mangoes from Brazil, it is recommended that the fruit be dipped in water 12 cm deep at 46.1 °C for 70 to 90 minutes (Gorgatti Neto *et al.,* 1994).

Table 4: **Combinations of temperature and exposure time for fruit fly quarantine treatments**

Time (days)	Maximun temperature (°C)	
	Ceratitis capitata	*Anastrepha fraterculus*
10	0,0	
11	0,6	0,0
12	1.1	
13		0,6
14	1,7	
15		1,1
16	2,2	
17		1,7

Adapted from Gorgatti Netto, *et al.,* 1993.

Many tropical crops are exposed to hot and humid air (40 to 50 °C for up to 8 hours) or water vapour to reach a pulp temperature that is lethal to insects. Hot air is well tolerated by mangoes, grapefruit, navel oranges, carambola, persimmon and papaya. Similarly, vapour treatments have been approved by the USDA-APHIS (U.S. Department of Agriculture, Animal and Plant Health Inspection Service) for clementines, grapefruits, oranges, mangoes, peppers, eggplants, papayas, pineapples, tomatoes and zucchinis (U.S. E.P.A., 1996).

2.2.3.7 Sprout suppression

Sprouting and root formation hasten the deterioration of potatoes, garlic, onions and other crops and also determine the marketability of these products. Consumers strongly reject sprouting or rooting products.

After development, bulbs, tubers and some root crops enter into a state of "rest" characterized by reduced physiological activity, which does not respond to environmental conditions. In other words, they do not sprout even when they are placed under ideal conditions of temperature and humidity. Different studies show that during rest, endogenous sprout inhibitors like abscisic acid predominate over promoters like gibberellins, auxins and others. This balance changes with the length of storage time and causes a "dormant" period. They will then sprout or form roots if placed under favourable environmental conditions. There are no clear-cut boundaries between these stages. Instead, there is a slow transition from one to the other as the balance between promoters and inhibitors changes. With longer storage times, promoters predominate and sprouting takes place.

Refrigeration and controlled atmosphere reduce sprouting and rooting rates but, because of their costs, chemical inhibition is preferred. Maleic hydrazide is sprayed on onions and garlic before harvest while CIPC (3-chloroisopropyl-N-phenylcarbamate) is applied to potatoes prior to storage in the form of dust or vapour or by immersion or other forms of application. As CIPC interferes with periderm formation, it must be applied after curing is completed.

2.2.3.8 Gas treatments before storage

Different studies have shown that exposure of fruit to an atmosphere rich in carbon dioxide (10 to 40 percent up to a week) before storage contributes towards maintaining quality in grapefruits, clementines, avocados, nectarines, peaches, broccoli and berries (Artés Calero, 2000). Control of insects is possible with higher concentrations (60 to 100 percent). The effect of this gas is not well understood. What is known is that it has an inhibitory effect on metabolism and ethylene action and the effect is persistent after treatment. Also, higher concentrations (> 20 percent) inhibit spore germination and the growth of decay organisms.

Exposure to an atmosphere with very low oxygen (< 1 percent) also contributes towards preserving quality and controlling insects in oranges, nectarines, papaya, apples, sweet potatoes, cherries and peaches (Artés Calero, 2000). Lowering oxygen concentration reduces the respiratory rate and the metabolism in general.

2.2.4 Packaging

Packaging is the act of putting the produce inside a container along with packing materials to prevent movement and to cushion the produce (plastic or moulded pulp trays, inserts, cushioning pads, etc.) and to protect it (plastic films, waxed liners, etc.). Packaging must satisfy three basic objectives:

1. Contain product and facilitate handling and marketing by standardizing the number of units or weight inside the package.
2. Protect product from injuries (impact, compression, abrasion and wounds) and adverse environmental conditions (temperature, relative humidity) during transport, storage and marketing.
3. Provide information to buyers, such as variety, weight, number of units, selection or quality grade, producer's name, country and area of origin. Frequently included are recipes, nutritional value, bar codes or any other relevant information on traceability.

A well-designed package needs to be adapted to the conditions or specific treatments required for the product. If hydrocooling or ice-cooling is required, the package must tolerate wetting without losing strength. For a product with a high respiratory rate, the packaging should have sufficiently large openings to allow good gas exchange. When produce dehydrates easily, the packaging should be designed to provide a good barrier against water loss, etc. Semi-permeable materials make it possible to generate special atmospheres inside packages. This helps in maintaining produce freshness.

2.2.4.1 Categories of packaging

There are three types of packaging:

1. consumer units or prepackaging
2. transport packaging
3. unit load packaging or pallets

When weighed produce reaches the consumer in the same type of container in which it is prepared, it is described as a consumer unit or prepackaging. It normally contains the quantity a family consumes during a certain period of time (300 g to 1.5 kg, depending on produce). Materials used include moulded pulp or expanded polystyrene trays wrapped in shrinkable plastic films (Figure 40), plastic or paper bags, clamshells, thermoformed PVC trays, etc. Onions, potatoes and sweet potatoes are marketed in mesh bags containing from 3 to 5 kg. Colours, shapes and textures of packaging materials play a role in improving appearance and attractiveness.

Transport or packaging for marketing usually consists of fibreboard or wooden boxes weighing from 5 to 20 kg or bags which can be even heavier (Figure 41). Packaging must be easy to handle, stackable by one person and have the appropriate dimensions in order to fit into transport vehicles. Materials used should be biodegradable, non-contaminating and recyclable. Packaging intended for repeated use should be easy to clean and to dismantle so that it is possible to significantly reduce volume on the return trip. These packages should be able to withstand the weight and handling conditions they were designed for (Figure 42) and to meet the weight specifications or count without overfilling (Figure 43).

In these types of packages it is common to use packaging materials which serve as dividers and immobilize the fruit such as vertical inserts. They also assist in reinforcing

Figure 40: **Consumer packaging or prepackaging.**

the strength of the container, particularly when large or heavy units such as melons or watermelons are packed. Trays also have the same objective but they separate produce in layers. They are commonly used for apples, peaches, plums, nectarines, etc. Plastic foam nets are used for the individual protection of large fruits like watermelon (Figure 44), mango, papaya, etc. It is also possible to use paper or wood wool, papers or other loose-fill materials.

In many developing countries containers made of natural fibre are still used for the packaging of fruits and vegetables (Figure 45). Although inexpensive, they cannot be cleaned or disinfected and therefore represent a source of contamination of microorganisms when reused. Moreover, there is a risk of bruising as a result of compression because these containers were not designed for stacking. In addition, the significant variations in weight and volume make marketing a complex business.

Finally, pallets have become the main unit loads of packaging at both domestic and international levels. Their dimensions correspond to those of maritime containers, trucks, forklifts, storage facilities, etc. When pallets are used as unit loads, handling is reduced in all the steps of the distribution chain. Different sizes exist; however, the most commonly used internationally measures 120 x 100 cm and is sometimes made of plastic materials. Depending on the packaging dimensions, a pallet may hold from 20 to 100 units. To ensure stability, pallet loads are secured with wide-mesh plastic tension net-

Figure 41: **Different packaging containers for fruits and vegetables.**

Figure 42: **Weak containers or inadequate stacking patterns may collapse producing compression damages.**

ting (Figure 46) or a combination of corner post protectors and horizontal and vertical plastic strapping (Figure 47). In many cases individual packages are glued to each other with low tensile strength glue that allows for separate units but prevents sliding. They are also stacked crosswise or interlocked to contribute to the load stability.

There is a trend towards standardization of sizes because of the wide variety of shapes and sizes of packaging for fruits and vegetables. The main purpose of standardization is to maximize utilization of the pallet's surface based on the standard size 120 x 100 cm. The ISO (International Standards Organization) module (norm ISO 3394) sets 60 and 40 cm as basic horizontal dimensions divided in sub-units of 40 x 30 cm and 30 x 20 cm (Figure 48). There are no regulations regarding the height of individual packages. However, in order to ensure safe handling, the palletized load should not exceed 2.05 m. On the recommendation of the United States Department of Agriculture (USDA) the

Figure 43: **Overfilling containers is the main reason for compression damages.**

Figure 44: **Individual protection of large fruits.**

Figure 45: **Natural fibre containers for vegetables.**

Figure 46: **Pallet stabilization using mesh plastic tension netting.**

Figure 47: **Pallet stabilization using corner posts and strapping.**

MUM system (Modularization, Unitization and Metrication) also has as its objective container standardization on the basis of the 120 x 100 cm pallet.

The trend towards the use of non-returnable containers poses an environmental challenge. To reduce the impact, packages must be designed to meet their functional objectives with minimal wastage of materials. They should also be recyclable after their main functional use.

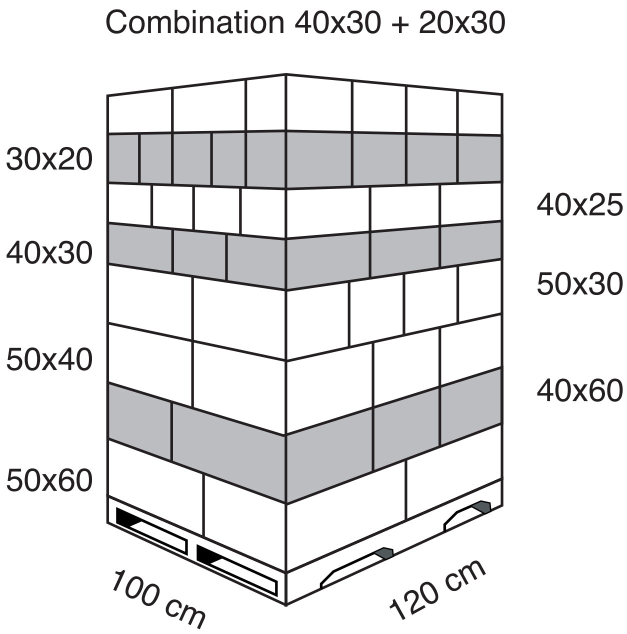

Figure 48: **Different horizontal package dimensions to maximize utilization of a 100 x 120-cm pallet, according to MUM and ISO (shaded) systems.**

Chapter 3

Storage

3.1 The need for storage

In temperate areas most fruit and vegetable production is seasonal. In contrast, cultivation and harvest periods are much longer in tropical and subtropical areas. Demand is year round and it is normal practice to use storage in order to ensure continuity of supply. Storage is also used as a strategy for achieving higher returns. Produce can be held temporarily to overcome gluts thus limiting price falls or to address shortage periods when prices are high.

Storage time depends on the intrinsic characteristics and perishability of the product. Shelf life ranges from short periods for products such as raspberries and other berries to long periods for products such as onions, potatoes, garlic and pumpkins. Storage conditions also depend on specific product characteristics. For example, leafy vegetables tolerate temperatures close to 0 °C, while most tropical fruits cannot tolerate exposure to temperatures below 10 °C.

In order to optimize storage conditions, only one crop should be stored in a room unless it is for a short period of time. Using the same storage area for different products can result in product damage because of incompatibility of temperature and relative humidity conditions, chilling and ethylene sensitivity, odour contamination and other problems affecting shelf life and quality.

3.2 Requirements and general characteristics for a storage facility

Generally, storage facilities are linked or integrated to packinghouses or other areas where there is a concentration of produce. However, often produce can be stored on-farm, either naturally or in specifically designed facilities. Location and design have an impact on system operations and efficiency even when mechanical refrigeration is used. Climate is an important factor for the location of the storage facility. For example, altitude reduces temperature by 10 °C for every 1 000 meters of elevation. It also increases the overall efficiency of refrigeration equipment by facilitating heat exchange with ambient temperature, thereby reducing energy costs. Shading, particularly of loading

Table 5: **Recommended temperature and relative humidity for fruits and vegetables and the approximate storage life under these conditions**

CROP	TEMPERATURE (°C)	RELATIVE HUMIDITY (%)	STORAGE LIFE (days)
A-B			
Amaranth	0-2	95-100	10-14
Apple	-1-4	90-95	30-180
Apricot	-0.5-0	90-95	7-21
Artichoke	0	95-100	14-21
Asian pear	1	90-95	150-180
Asparagus	0-2	95-100	14-21
Atemoya	13	85-90	28-42
Avocado	3-13	85-90	14-56
Babaco	7	85-90	7-21
Banana - Plantain	13-15	90-95	7-28
Barbados cherry	0	85-90	49-56
Basil	7-10	85-95	7
Bean (dry)	4-10	40-50	180-300
Beet (bunched)	0	98-100	10-14
Beet (topped)	0	98-100	120-180
Belgian endive	0-3	95-98	14-28
Blackberry	-0.5-0	90-95	2-3
Black sapote	13-15	85-90	14-21
Blueberries	-0.5-0	90-95	14
Bok Choy	0	95-100	21
Breadfruit	13-15	85-90	14-42
Broadbeans	0-2	90-98	7-14
Broccoli	0	95-100	14-21
Brussels sprouts	0	95-100	21-35
C-D-E			
Cabbage	0	98-100	150-180
Cactus leaves	2-4	90-95	14-21
Caimito	3	90	21
Calamondin	9-10	90	14
Cantaloupe (half slip)	2-5	95	15
Cantalupo (full slip)	0-2	95	5-14
Carambola	9-10	85-90	21-28
Carrot (bunched)	0	95-100	14
Carrot (topped)	0	98-100	210-270
Cassava	0-5	85-96	30-60

Table 5: **(cont.)**

CROP	TEMPERATURE (°C)	RELATIVE HUMIDITY (%)	STORAGE LIFE (days)
Cashew apple	0-2	85-90	35
Cauliflower	0	95-98	21-28
Celery	0	98-100	30-90
Celeriac	0	97-99	180-240
Chayote	7	85-90	28-42
Cherimoya	13	90-95	14-28
Cherries	-1-0.5	90-95	14-21
Chicory	0	95-100	14-21
Chinese cabbage	0	95-100	60-90
Chives	0	95-100	14-21
Coconut	0-1.5	80-85	30-60
Cranberries	2-4	90-95	60-120
Cucumber	10-13	95	10-14
Currants	-0,5-0	90-95	7-28
Custard apple	5-7	85-90	28-42
Daikon	0-1	95-100	120
Dates	-18-0	75	180-360
Durian	4-6	85-90	42-56
Eggplant	8-12	90-95	7
Escarole	0	95-100	14-21
F-G-H-I-J-K-L			
Fennel	0-2	90-95	14-21
Feijoa	5-10	90	14-21
Fig	-0.5-0	85-90	7-10
Garlic	0	65-70	180-210
Ginger	13	65	180
Grape	-0.5-0	90-95	14-56
Grapefruit	10-15	85-90	42-56
Green onions	0	95-100	21-28
Guanabana	13	85-90	7-14
Guava	5-10	90	14-21
Horseradish	-1-0	98-100	300-360
Husk tomato	13-15	85-90	21
Jaboticaba	13-15	90-95	2-3
Jackfruit	13	85-90	14-42
Jerusalem artichoke	-0.5-0	90-95	120-150
Jicama	13-18	65-70	30-60
Kale	0	95-100	10-14
Kiwano	10-15	90	180
Kiwifruit	-0.5-0	90-95	90-150
Kohlrabi	0	98-100	60-90

Table 5: **(cont.)**

CROP	TEMPERATURE (°C)	RELATIVE HUMIDITY (%)	STORAGE LIFE (days)
Kumquat	4	90-95	14-28
Leek	0	95-100	60-90
Lemon	10-13	85-90	30-180
Lettuce	0-2	98-100	14-21
Lima bean	3-5	95	5-7
Lime	9-10	85-90	42-56
Longan	1-2	90-95	21-35
Loquat	0	90	21
Lychee	1-2	90-95	21-35
M-N-O-P-Q-R			
Malanga	7	70-80	90
Mamey	13-18	85-95	14-42
Mandarin	4-7	90-95	14-28
Mango	13	90-95	14-21
Mangosteen	13	85-90	14-28
Melon (Others)	7-10	90-95	12-21
Mushrooms	0-1.5	95	5-7
Nectarine	-0.5-0	90-95	14-28
Okra	7-10	90-95	7-10
Onions (dry)	0	65-70	30-240
Olives, fresh	5-10	85-90	28-42
Orange	0-9	85-90	56-84
Papaya	7-13	85-90	7-21
Parsley	0	95-100	30-60
Parsnip	0	95-100	120-180
Passionfruit	7-10	85-90	21-35
Peach	-0.5-0	90-95	14-28
Pear	-1.5-0.5	90-95	60-210
Peas	0	95-98	7-14
Cucumber	5-10	95	28
Pepper (bell)	7-13	90-95	14-21
Persimmon	-1	90	90-120
Pineapple	7-13	85-90	14-28
Pitaya	6-8	85-95	14-21
Plum	-0.5-0	90-95	14-35
Pomegranate	5	90-95	60-90
Potato (early)	7-16	90-95	10-14
Potato (late)	4.5-13	90-95	150-300
Prickly pear	2-4	90-95	21
Pumpkins	10-15	50-70	60-160
Quince	-0.5-0	90	60-90

Table 5: **(cont.)**

CROP	TEMPERATURE (°C)	RELATIVE HUMIDITY (%)	STORAGE LIFE (days)
Radichio	0-1	95-100	14-21
Radish	0	95-100	21-28
Rambutan	10-12	90-95	7-21
Raspberries	-0.5-0	90-95	2-3
Rhubarb	0	95-100	14-28
Rutabaga	0	98-100	120-180
S-T-U-V-W-X-Y-Z			
Salsify	0	95-100	60-120
Sapodillla	15-20	85-90	14-21
Scorzonera	0	95-98	180
Snapbeans	4-7	95	7-10
Snowpeas	0-1	90-95	7-14
Spinach	0	95-100	10-14
Sprouts	0	95-100	7
Strawberry	0-0.5	90-95	5-7
Sweet corn	0-1.5	95-98	5-8
Sweet potato	13-15	85-90	120-210
Swiss chard	0	95-100	10-14
Summer squash	5-10	95	7-14
Tamarind	7	90-95	21-28
Taro	7-10	85-90	120-150
Tart cherries	0	90-95	3-7
Tomato (MG)	12.5-15	90-95	14-21
Tomato (red)	8-10	90-95	8-10
Tree tomato	3-4	85-90	21-28
Turnip	0	90-95	120
Watercress	0	95-100	14-21
Watermelon	10-15	90	14-21
White sapote	19-21	85-90	14-21
Yam	16	70-80	60-210
Yellow sapote	13-15	85-90	21

Source: Cantwell, 1999; Sargent, *et al.,* 2000; McGregor, 1987.

and unloading areas, reduces thermal differences between field and storage temperatures.

Building design is an important factor to be taken into consideration. For example, a square shaped floor perimeter is thermally more efficient than a rectangular one. The roof is the most important part of the structure because it has to protect produce from rain and radiant heat. Its slope should allow for the easy fall-off of rainwater; its dimensions should exceed the perimeter of the building to protect walls from the sun and to provide a dry area around the building in rainy weather. Floors should be made of concrete, isolated from soil humidity and elevated to avoid penetration of water. Doors need to be wide enough for mechanized handling.

Storage facilities should be thoroughly cleaned before filling. This includes brushing and washing walls and floors to eliminate dirt and organic debris that could harbour insects and diseases. Before produce is placed in the storage room, inspection and pre-sorting should be carried out in order to remove all potential sources of contamination for the remaining load. The produce should be stacked in such a way that there is free circulation of air. During the storage period, it should also be possible to carry out quality control inspections. If the storage facility becomes full during a long harvest period, it needs to be organized on a “first in-first out” basis.

3.3 Storage systems

There are many ways of storing a product. The length of storage time can be longer in specifically designed structures. With refrigeration and controlled atmospheres, storage periods can be even longer. The technology utilized depends on whether the benefits (higher prices) outweigh the costs.

3.3.1 Natural or field storage

This is the most rudimentary system and is still in use for many crops such as roots (carrots, sweet potatoes, and cassava) and tubers (potatoes). Crops are left in the soil until preparation for the market. This is similar to the way citrus and some other fruits are left on the tree. Although natural storage is widely practised, it leaves products exposed to pests and diseases as well as to adverse weather conditions that can have a detrimental effect on quality.

Another method widely used is field storage in heaps. This method ensures that produce is free from soil humidity and is protected from the weather with a tarpaulin, straw, or plastic materials (Figure 49). It is a low-cost alternative for bulky crops that require large buildings such as potatoes, onions, pumpkins and sweet potatoes. Field storage in bins is a more recent variation. A pair of bins is left in the field, one on top of the other, with the one above protected from the weather. This system has the additional advantage of making it possible to carry out mechanical handling later.

3.3.2 Natural ventilation

Amongst the wide range of storage systems, natural ventilation is the simplest. It takes advantage of the natural airflow around the product to remove the heat and humidity generated by respiration. Structures that provide some form of protection from the external environment and gaps for ventilation can be used. Produce is placed in bulk, bags, boxes, bins, pallets, etc. (Figure 50). Although simple, some key concepts must be taken into account for the efficient operation of this system.

1. Differences in internal temperature and relative humidity conditions compared with external conditions need to be minimal. This system can only be used with crops that store well under natural conditions such as potatoes, onions, sweet potatoes, garlic and pumpkins.
2. Openings need to be wide for adequate ventilation and they should be fitted with screens to keep out animals, rodents and pests.
3. As with fluids, air follows the path of least resistance. If produce is stored in a compact mass, air will circulate to remove heat and gases that have accumulated as a result of respiration. Efficient ventilation requires adequate space; however, this reduces storage capacity.
4. Hot and humid air rises within the storage facility. If no ventilation gaps exist, hot and humid areas build up, which in turn affect the quality of stored goods and create ideal conditions for the development of disease.

Within certain limits, it is possible to take advantage of natural changes in temperature and relative humidity by selectively opening and closing storage ventilation. At noon, ambient temperature and relative humidity are higher and lower, respectively. However, at night the opposite happens. To reduce the temperature of stored products, buildings should be left open when external air temperatures are lower. Internal relative humidity can also be managed in a similar way.

External conditions constantly change, even during the same day. However, in comparison to air, stored mass is slower to gain and release heat. In order to handle this efficiently, internal and external electronic sensors for temperature and relative humidity are required. Although crops suitable for this type of storage have low respiratory rates, some ventilation may be required in addition to the automated opening and closing schedules.

3.3.3 Forced-air ventilation

Heat and gas exchange can be improved provided air is forced to pass through the stored produce. This system allows for more efficient utilization of space for bulk storage. Air conducts run under a perforated floor (Figure 51) and air is forced through the produce. As air follows the path of least resistance, loading patterns as well as fan capacity and conduct dimensions should be carefully calculated to ensure that there is uniform distribution of air throughout the stored produce.

Removable perforated ducts can be used for storage space when there are no products in storage (Figure 52).

Figure 49: **Field storage of onions in heaps covered with straw.**

Figure 50: **Storing garlic in shelters with natural ventilation.**

Fan selection is the most critical factor and specialized personnel should design the system based on volume and number of air changes per unit of time required. The latter is a function of respiratory rates of products to be stored. Static pressure or resistance to the airflow by conducts and stored mass should be considered. Ideally, sensors reacting to the internal/external ambient relationship should control the system. If closed, only internal air circulation occurs. On the other hand, if opened, internal atmosphere is replaced by ventilation. A partial opening produces a mix of internal and external air to reach the desired combination of temperature and relative humidity.

3.3.4 Refrigeration

Temperature control is one of the main tools for extending postharvest life. Low temperatures slow product metabolism and the activity of microorganisms responsible for quality deterioration. As a result, reserves are maintained with a lower respiration rate, ripening is retarded and vapour pressure between product and ambient is minimized, reducing water loss. These factors contribute towards maintaining freshness by reducing the rate at which quality deteriorates and the nutritional value of the product is preserved.

A refrigerated room is a relatively airtight and thermally insulated environment. The refrigeration equipment should have an external escape outlet to release the heat generated by the product. Refrigeration capacity of the equipment should be adequate to extract the heat generated by crops with a high respiration rate. It is also important to control precisely the temperature and relative humidity conditions inside the refrigerated storage environment.

The dimensions of the refrigerated room depend on the maximum storage volume needed. Other factors to be considered include walkways and aisles to handle the product mechanically and the additional space necessary to ensure uniform distribution of cold air. It is not uncommon to find that produce occupies only 75 to 80 percent of total surface area. Chamber height depends on product and stacking pattern: three metres are sufficient for and stacking but more than six metres may be required if forklifts are utilized.

Figure 51: **Forced-air storage facilities. Produce is piled up to the yellow line. Air from the floor openings is forced to pass through the stored mass. An inspection alley is located on the upper right-hand side with ladders to sample produce during storage.**

Figure 52: **Inside of a forced-air storage facility. Air conducts are removed and empty space is used to shelter farm machinery and equipment when there are no products in storage.**

Refrigerated rooms can be made with concrete, metal, wood or other materials. All external surfaces should be thermally insulated, including the floor and ceilings. Type and thickness of insulation material depend on building characteristics, produce to be stored and the difference in temperature required between external and internal conditions. Polyurethane, expanded polystyrene, cork and other such materials can be used as insulation materials. A vapour barrier should be placed on the warm side of the insulation material.

Mechanical refrigeration has two main components: the evaporator, inside the storage area; and the condenser, which is outside connected by tubing filled with refrigerant. Normally, both elements are finned coils made of high thermal conductivity materials and integrated to a fan that facilitates heat exchange. An evaporator is placed on the upper part of one of the walls (Figure 53) forcing cold air to flow parallel to the ceiling. Returning air is forced past the evaporator, transferring to the coil the heat extracted from the product. A refrigerant absorbs this heat as it changes to gas, cooling the air that is forced again into the room as cold air. The refrigerant is transported as gas to the condenser (outside of building) where under the pressure provided by a compressor, it is transformed again into liquid form. The internal heat is then released outside. With this repeated cycle, the system behaves like a pump – heat is extracted from the stored product and then released outside. Another key aspect of the mechanical refrigeration system is the expansion valve, which regulates the evaporation and flow of refrigerant. Ammonia and freon gas are the most widely used refrigerants; however, they are now being replaced by more environmentally friendly products.

In order to gain maximum benefit from refrigeration, its capacity must be adequate to extract respiration heat from the product as well as conductive heat (through floors, walls, and ceiling), convective heat gains (door openings) and the heat produced by equipment (forklifts, lights and pumps).

Every crop has an optimal combination of temperature and relative humidity for storage. In many cases there are differences even within varieties (Table 5). As previously mentioned, it is recommended not to store more than one crop in the same room unless it is for a very short period (less than a week) or during transportation. Crops that are highly incompatible should not be in the same room for more than one or two days.

3.3.4.1 Precooling

Refrigeration equipment is designed to keep produce chilled; however, it is not capable of reducing field heat rapidly. Field temperature is approximately the same as ambient temperature and is much higher if produce is not protected from the sun. When produce is exposed to colder ambient conditions, it slowly loses field temperature. It may take from 24 to 48 hours to reach the new ambient temperature. The rate at which temperature falls depends on a number of factors, which include differences in temperature, individual volume of product, total mass required for precooling and the capacity of refrigeration equipment. Metabolic activity (respiration, ethylene production, biochemical, and enzymatic reactions) also decreases with temperature. When storage temperature is reached rapidly, losses in energy, stored reserves, and quality are reduced.

Precooling is the rapid reduction of field temperature prior to processing, storage, or refrigerated transport. Generally it is a separate operation requiring special facilities, but complementary to cold storage. As deterioration is proportional to the time produce is exposed to high temperatures, precooling is beneficial even when produce is later returned to ambient conditions. It is critical in maintaining the quality of fruits and vegetables and forms part of the “cold chain” to maximize postharvest life.

Product temperature loss is not linear because it is rapid at the beginning but slows down as it approaches the medium refrigerating temperature. Operation costs increase for each degree reduced. In commercial operations, produce is precooled to reach seven-eighths of the difference between field and the final temperature required. The remaining one-eighth is lost during refrigerated storage or transport (Figure 54). For example, a product with a field temperature of 30 °C exposed to a refrigerating medium of 10 °C, is precooled when seven-eighths of the temperature difference is removed (final temperature = 12.5 °C)

$$T_{final} = T_{initial\ product} - [\ 7 \times (\ T_{initial\ product} - T_{refrigerant}\ ) / 8\ ]$$

$$T_{final} = 30 - [\ 7 \times (\ 30 - 10\ ) / 8\ ] = 12.5\ °C$$

The rate of cooling depends on individual volume and the exposed surface of product. The difference in temperature between product and the refrigerating medium also needs to be taken into account. For example, because they have large exposed surfaces, leafy vegetables cool almost five times faster than large fruit such as melons or watermelons. The type of cooling medium used and the amount of circulation surrounding the product also influence the rate of cooling. Water has more capacity to absorb heat than air and in both cases rapid circulation increases their cooling capacity.

Each system listed below has its advantages and disadvantages.

a. Cold air:	Room cooling
	Forced-air cooling
b. Cold water:	Hydrocooling
c. Contact with ice:	Crushed ice
	Liquid ice
	Dry ice
d. Evaporation of surface water:	
	Evaporative
	Vacuum cooling

3.3.4.1.1 Room cooling

Room cooling is the most widely used system and is based on the product's exposure to cold air inside a refrigerated room (Figure 53). It is simple to operate as the product is cooled and stored in the same room. However, the slow removal of heat makes this system unsuitable for highly perishable commodities because at least 24 hours is needed to reach the required storage temperature. Almost all other crops are suitable for this type of cooling; however, it is mainly used for potatoes, onions, garlic, citrus, etc. (Table 6).

3.3.4.1.2 Forced-air cooling

Cold air is forced to pass through produce by means of a pressure gradient across packages (Figure 55). Cooling is four to ten times more rapid than room cooling and its rate depends on airflow and the individual volume of produce.

Amongst the wide range of systems available, it is probably the most versatile because it can be used for all crops (Table 7), particularly berries, ripe tomatoes, bell peppers and many other fruits. It is slow compared to hydrocooling but is a good alternative for those crops that require rapid heat removal and cannot tolerate wetting or the chlorine contained in cooling water. However, inadequate airflow may produce dehydration. Package ventilation openings should be large enough to allow adequate air flow, particularly if products are stacked or palletized. Adequate airflow is necessary because fruits contained in the centre of packages tend to lose heat at a slower rate compared with those closer to the exterior.

3.3.4.1.3 Hydrocooling

The refrigerating medium for hydrocooling is cold water. Because of its higher capacity to absorb heat, it is faster than forced-air cooling. Hydrocooling can be achieved by immersion (Figure 56) or through means of a chilled water shower. In the latter case produce must be arranged in thin layers for uniform cooling. This system cannot be used for crops that do not tolerate wetting, chlorine and water infiltration. Tomatoes, asparagus and many other vegetables are hydrocooled commercially (Table 8). Chlorination of water (150-200 ppm) is important to prevent the accumulation of pathogens.

3.3.4.1.4 Ice cooling

Ice cooling is probably one of the oldest methods used to reduce field temperature. It is most commonly used for individual packages – crushed ice is placed on top of the produce before the package is closed. Ice layers may also be interspersed with produce. As

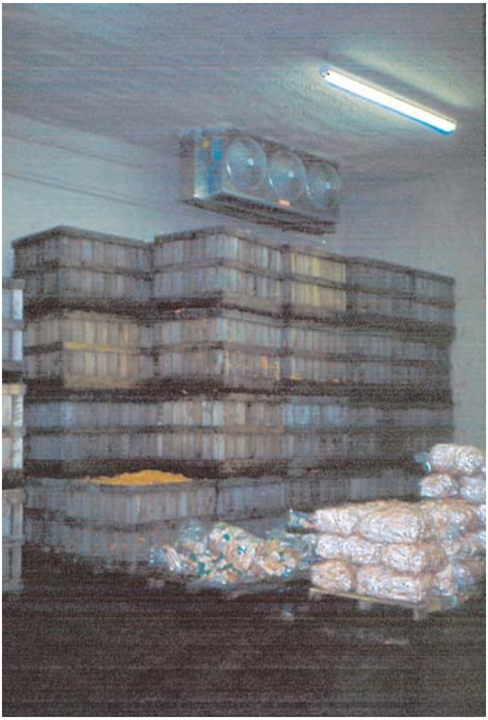

Figure 53: **Inside refrigerated storage. Evaporator is located on the upper part of one of the walls.**

it melts, cold water cools the lower layers of produce. Liquid icing is another system where a mix of water and crushed ice (40 percent water + 60 percent ice + 0.1 percent salt) is injected into open containers so that a big ice block is formed. The main disadvantage of ice cooling is that it is limited to ice-tolerant crops (Table 9). It also increases costs because of the heavier weight for transportation and the need for oversized packages. Another disadvantage is that as water melts, storage areas, containers and shelves become wet.

3.3.4.1.5 Evaporative

This is one of the simplest cooling systems. It involves forcing dry air through wet products. Heat is absorbed from the product as water evaporates. This method has a low energy cost but cooling efficiency is limited by the capacity of air to absorb humidity.

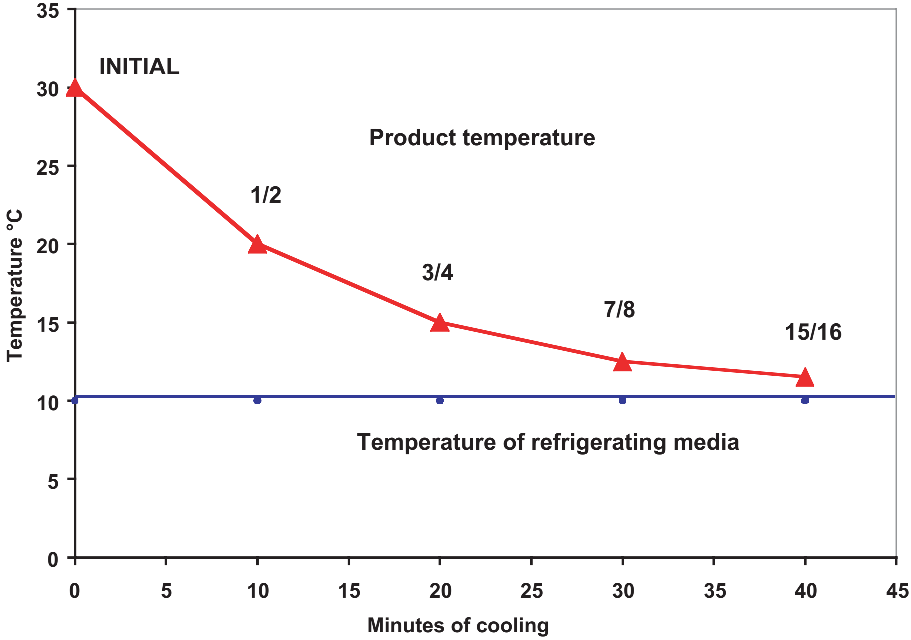

Figure 54: **Temperature loss of a product exposed to a refrigerating media.**

As a result, it is only useful in areas with very low relative humidity.

3.3.4.1.6 Vacuum cooling

Vacuum cooling is one of the more rapid cooling systems; however, cooling is accomplished at very low pressures. At a normal pressure of 760 mmHg, water evaporates at 100 °C, but it evaporates at 1 °C if pressure is reduced to 5 mmHg. Produce is placed in sealed containers where vacuum cooling is performed (Figure 57). This system produces about 1 percent product weight loss for each 5 °C of temperature reduction. Modern vacuum coolers add water as a fine spray in the form of pressure drops. Similar to the evaporation method, this system is in general appropriate for leafy vegetables because of their high surface-to-mass ratio (Table 10).

Table 6: **Crops usually room cooled**

Artichoke	Coconut	Melons	Salsify
Asian pear	Custard apple	Onion	Sapote
Atemoya	Garlic	Orange	Scorzonera
Banana	Ginger	Parsnip	Summer squash
Beans (dry)	Grapefruit	Cucumber	Sweet potato
Beet	Horseradish	Pineapple	Tangerine
Breadfruit	Husk tomato	Plantain	Tomato
Cabbage	J. artichoke	Potato	Tree tomato
Cactus leaves	Jicama	Prickly pear	Turnip
Carambola	Kiwano	Pumpkin	Watermelon
Cassava	Kohlrabi	Quince	Yam
Celeriac	Kumquat	Radish	
Chayote	Lime	Rhubarb	
Cherimoya	Lemon	Rutabaga	

Source: Sargent, *et al.,* 2000; McGregor, 1987.

3.3.4.2 Chilling injury

Refrigeration is the most widely used method for extending the postharvest life of fruits and vegetables. However, low temperatures may produce injuries to plant tissues. Freezing (prolonged exposure to temperatures lower than 0 °C) forms ice crystals inside tissues that cause damage. Symptoms are readily apparent when thawing occurs – there is a loss of turgidity and a general breakdown of plant tissues. Unattended or malfunctioning refrigeration equipment is the main cause of chilling injuries.

Chilling injuries are less noticeable on crops that do not tolerate long exposure to temperatures that range from 0 to 15 °C. Most chilling-sensitive crops are of tropical or subtropical origin, such as tomatoes, peppers, eggplants, pumpkins, summer squash, sweet potatoes and bananas. Some temperate crops may also be sensitive, for example, asparagus, potatoes, some apple varieties and peaches. Critical temperatures for these crops range from 0 to 5 °C, while those of tropical origin range from 7 to15 °C.

Symptoms of chilling injury depend on the type of crop and become noticeable when product is returned to ambient temperature. In bananas, for example, a blackening of the skin and softening takes place while in tomatoes, peppers, eggplants and other fruits, sunken areas are apparent. This is usually associated with decay organisms

(Figure 58) and followed by rapid and uneven ripening. In many cases internal darkening or other discoloration is present. Severity of chilling injury depends on crop, temperature and length of exposure. As a general rule, immature fruits are more susceptible to damage than mature ones.

From a physiological point of view, chilling injury is the result of a cumulative breakdown of cellular metabolism that is reversible during the first phase. A small rise in temperature restores the product to its former condition provided injuries are of a temporary nature. Different studies show that periodic (from 6 to 15 days) and short interruptions (5 to 48 hours) of cold storage through increases in temperature (from 12 to 25 °C) contribute towards extending postharvest life (Fern·ndez Trujillo, 2000). Chilling injury is cumulative and in many cases it is the result of field storage and/or low transport temperatures.

3.3.4.3 Ethylene and other gaseous contamination

Under relatively airtight storage conditions, metabolic gases accumulate and ethylene and other volatiles are some of the most frequent contaminants.

Table 7: **Crops normally precooled by forced air**

Anona	Coconut	Mango	Prickly pear
Atemoya	Cucumber	Mangosteen	Pumpkin
Avocado	Eggplant	Melons	Quince
Banana	Feijoa	Mushrooms	Rhubarb
Barbados cherry	Fig	Okra	Sapote
Berries	Ginger	Orange	Snapbeans
Breadfruit	Grape	Papaya	Snowpeas
Brussels sprouts	Grapefruit	Passionfruit	Strawberry
Cactus leaves	Guava	Pepino	Summer squash
Caimito	Husk tomato	Pepper (Bell)	Tangerine
Carambola	Kiwifruit	Persimmon	Tomato
Cassava	Kumquat	Pineapple	Tree tomato
Chayote	Lima bean	Plantain	Yam
Cherimoya	Lychee	Pomegranate	

Source: Sargent, *et al.,* 2000; McGregor, 1987.

Table 8: **Crops normally hydrocooled**

Artichoke	Cassava	Kiwifruit	Radish
Asparagus	Celeriac	Kohlrabi	Rhubarb
Beet	Celery	Leek	Salsify
Belgian endive	Chinese cabbage	Lima bean	Snapbeans
Broccoli	Cucumber	Orange	Snowpeas
Brussels sprouts	Eggplant	Parsley	Spinach
Caimito	Escarole	Parsnip	Summer squash
Cantaloupe	Green onions	Peas	Sweet corn
Cauliflower	Horseradish	Pomegranate	Swiss chard
Carrot	J. artichoke	Potato (early)	Watercress

Source: Sargent, *et al.*, 2000; McGregor, 1987.

Ethylene is a phytohormone, which regulates many growth, development and senescence processes in plant tissues. It is produced in large quantities by climacteric fruits during ripening. It is also induced by certain types of stress such as physical injuries and forms part of the healing process. Ethylene is released as a gas and accumulates to physiologically active levels when not eliminated by ventilation or chemical means.

When ethylene-releasing and sensitive crops are placed in the same room, undesirable reactions take place (Table 11). These include, for example, an increase in respiratory rate, ripening and senescence, loss of green colour, yellowing, necrotic areas on plant tissues, formation of abscission layers, sprouting in potatoes, development of bitter flavour in roots and asparagus toughening. Indirect effects include an increase in sensitivity to chilling, susceptibility to pathogens and the stimulation of some decay organisms. The level of ethylene in storage areas should be less than 1 ppm to avoid problems.

Aroma, odours, and other volatiles form an integral part of the metabolism of the plant. As with ethylene, contamination occurs when producing species and sensitive crops share the same storage area (Table 11).

3.3.4.4 Relative humidity

Fruits and vegetables are composed largely of water. An important factor in maintaining postharvest quality is to ensure that there is adequate relative humidity inside the storage area. Water loss or dehydration means a loss in fresh weight, which in turn

Figure 55: **Inside a forced-air precooling facility. Pallets are arranged to form an aisle. Tops are covered with a canvas leaving both sides exposed to cold air. Air from the plenum tunnel is removed creating a negative pressure that forces cold air to pass through the load.**

affects the appearance, texture and, in some cases, the flavour. Water loss also affects crispiness and firmness. Consumers tend to associate these qualities with recently harvested fresh produce.

The percentage of relative humidity is the most widely used parameter to express the amount of water in the air. It is defined as the relationship between the pressure of water in the air and the temperature at saturation point. As with other gases, water vapour moves from higher to lower pressure areas. In plant tissues, water is mainly present as cellular liquid, but in equilibrium with the intercellular spaces where it exists as a vapour saturated atmosphere (100% relative humidity). Exposure to identical conditions of relative humidity and temperature will prevent water loss from tissues.

Figure 56: **Hydrocooling produce and direct loading to a truck.**

Capacity of air to hold water increases with temperature and the reverse is also true. This means that refrigeration increases the relative humidity of air. In some cases humidifiers are needed to increase the moisture content in order to reach the ideal conditions for storage. Most fruits and vegetables should be kept at a relative humidity of 90 to 95 percent, while some others at values close to saturation (Table 5). Some exceptions are onions, garlic and pumpkins, which are best stored at relative humidity ranging from 60 to 70 percent.

3.3.4.5 Short term storage – Refrigerated transport

Refrigeration in cold stores is not always used to maximize postharvest life. On the contrary, it is probably used more often during the short time required for the sequence of activities in the cold chain ending at the consumption point. Refrigerated transport is probably the best example of this; however, there are many other opportunities for the use of temporary cold storage such as during the preparation and sale of produce for the market. For example, it is used for holding produce until processing, packaging, or transport is carried out. Other examples include the use of refrigerated facilities at the wholesale or retail level. Cold storage is also used in the home to prolong the shelf life of products.

It is difficult to define what constitutes "short term and long-term storage". Seven days is a long time for the storage of raspberries, while for potatoes, onions, garlic and other

Table 9: **Crops that can be ice cooled**

Belgian endive	Chinese cabbage	Kohlrabi	Spinach
Broccoli	Carrot	Leek	Sweet corn
Brussels sprouts	Escarole	Parsley	Swiss chard
Cantaloupe	Green onions	Pea/snowpeas	Watercress

Source: Sargent, *et al.,* 2000; McGregor, 1987.

Table 10: **Crops that can be vacuum cooled.**

Belgian endive	Celery	Mushrooms	Sweet corn
Brussels sprouts	Escarole	Radiccio	Swiss chard
Carrot	Leek	Snapbeans	Watercress
Cauliflower	Lettuce	Snowpeas	
Chinese cabbage	Lima bean	Spinach	

Source: Sargent, *et al.,* 2000; McGregor, 1987.

products that tolerate longer periods of storage, this is considered to be relatively short. In this manual, "short-term storage" is defined as a period ranging from a couple of hours up to approximately seven days.

It is preferable not to store different crops together. This is common practice, however, and is unavoidable in many cases, particularly at distribution or retail levels. This does not pose a problem provided products are not exposed to sub-optimal conditions for too long and build up of ethylene is avoided. A strategy widely practised is to set cold chambers at an average of around 5 °C and 90 to 95 percent relative humidity.

If possible, mixed loads should have different regimes depending on the specific combination of fruits and vegetables in store. This is assuming that ambient ethylene concentration does not exceed 1 ppm. The University of California (Thompson *et al.,* 1999) recommends three combinations of temperature and relative humidity (RH): 1) 0-2 °C and 90-98 percent RH for leafy vegetables, crucifers, temperate fruits and berries; 2) 7-10 °C and 85-95 percent RH for citrus, subtropical fruits and fruit vegetables;

Figure 57: **Vacuum cooling. Both cooler ends are lifted to allow moving produce in and then closed to create a vacuum.**

Figure 58: **Symptoms of chilling injury are usually small depressed areas on fruit surface that are later colonized by deteriorating microorganisms.**

3) 13-18 °C and 85-95 percent RH for tropical fruits, melons, pumpkins and root vegetables. On the other hand, Tan (1996) recommends five different storage conditions: 1) 0 °C and 90-100 percent RH; 2) 7-10 °C and 90-100 percent RH; 3) 13 °C and 85-90 percent RH; 4) 20 °C; and 5) ambient conditions. Other species are divided into five groups. Group one includes apples, apricots, figs, ripe kiwifruit, peaches, pears, leafy vegetables, grapes, beets, crucifers and celery. Group two includes avocados, cantaloupes, honeydew melons, guava, cucumber, snap beans, peppers, summer squash, eggplants and citrus in general. Group three contains bananas, cherimoya, papayas, potatoes and pumpkins. Group four includes pineapple, while group five contains garlic, nuts, onions, potatoes and shallots.

Transport is an example of temporary refrigerated storage. Mixed loads cause incompatibility problems as highlighted previously. Because packaging dimensions are different, the produce is usually not fully stackable. In addition, the ventilation openings of packages of different dimensions do not match each other, which prevents ventilation and creates undesirable micro-ambient conditions.

3.3.5 Combination of storage systems

Facilities for long-term storage of potatoes, onions and sweet potatoes often include using a combination of forced-air systems as well as heating and/or refrigeration equipment. Because these are crops that initially require a curing period, hot and humid air is introduced at the beginning. Later, the temperature is reduced either through forced-air cooling or natural ventilation. Adequate temperatures are obtained by mixing external and internal atmospheres and, if required, the air is heated or refrigerated. In this way, the same building is used for both curing and storage – an important consideration in mechanized harvesting systems.

3.3.6 Controlled atmospheres

With atmosphere modification, the low metabolic rate achieved with refrigeration is extended even further. As a result, the storage period is prolonged without further losses in quality.

The composition of normal atmosphere at sea level is around 78.1 percent nitrogen, 21 percent oxygen and 0.03 percent carbon dioxide. A “controlled” or “modified” atmosphere is obtained when its composition varies from the norm. In controlled atmosphere, gas composition is exactly maintained. It is often used for extremely long periods of storage in purpose-built facilities. Modified atmospheres, on the other hand, are obtained when produce is packed in semi-permeable films for short periods. The atmos-

Table 11: **Ethylene and odour producer crops and ethylene and odour sensitive crops**

	Ethylene producer	Ethylene sensitive	Odor producer	Odor sensitive
Anona	X	X		
Apple	X	X	X	X
Apricot	X	X		
Asian pear	X	X		
Asparagus		X		
Atemoya	X	X		
Avocado	X	X	X	X
Banana	X	X		
Basil		X		
Belgian endive		X		
Broccoli		X		
Brussels sprouts		X		
Cabbage		X		X
Cactus leaves		X		
Carrot		X	X	X
Cauliflower		X		
Celery		X		X
Cherimoya	X	X		
Cherry				X
Chinese cabbage		X		
Chives		X		
Cucumber		X		
Dates				X
Eggplant		X		X
Escarole		X		
Feijoa	X			
Fig	X			X
Grape			X	X
Green onions		X	X	
Guava	X	X		
Husk tomato		X		
Jackfruit	X	X		
Kale		X		
Kiwano		X		
Kiwifruit	X	X		
Leek		X	X	
Lemon			X	
Lettuce		X		
Lima bean		X		
Lime			X	
Lychee	X	X		

Table 11: **(cont.)**

	Ethylene producer	Ethylene sensitive	Odor producer	Odor sensitive
Mandarin		X		
Mango	X	X		
Melons	X	X		
Mushrooms	X	X		X
Nectarines	X	X		
Okra		X		
Olives, fresh		X		
Onion			X	X
Oranges		X	X	
Papaya	X			
Parsley		X		
Parsnip		X		
Passionfruit	X	X		
Pea		X		
Peach	X	X		
Pear	X	X	X	X
Pepino		X		
Pepper (Bell)		X	X	
Persimmon	X	X		
Prickly pear		X		
Pineapple				X
Plum	X	X		
Potato		X	X	X
Quince	X	X		
Rambutan	X	X		
Sapodilla	X	X		
Sapote	X	X		
Snapbeans		X		X
Snowpeas		X		
Spinach		X		
Summer squash		X		
Sweet corn				X
Sweet potato		X		
Swiss chard		X		
Tomato	X	X		
Watercress		X		
Watermelon		X		
Yam		X		

Source: The Packer, 1996; Gast and Flores, 1992; McGregor, 1987; Cantwell, 1999.

pheric composition inside the package changes until it is in equilibrium with the ambient conditions. Equilibrium atmosphere depends on product, film characteristics and storage temperature.

The modification of storage atmosphere delays the biochemical and physiological changes associated with senescence. This mainly involves the respiratory rate, ethylene production, softening and compositional changes. Other effects include the reduction in sensitivity to ethylene and, in some cases, chilling and the severity of pathogen attack. The atmospheric composition can also be used to control insects. The risk of using abnormal atmospheres is that they may cause fermentation, tissue asphyxia (Figure 59) and the development of off-odours or off-flavours.

From the construction point of view, controlled atmosphere facilities are similar to refrigeration facilities. However, they should be airtight to allow for the creation of an atmosphere different from normal. Oxygen consumption and its replacement by carbon dioxide by respiration, create the atmosphere. When the appropriate combination has been reached, a limited intake of oxygen is required to satisfy the reduced rate of respiration. Accumulation of carbon dioxide is removed by means of different methods. A pressure compensating system is required to attain equilibrium with the external or ambient atmosphere. As controlled atmosphere rooms are kept locked until the end of the storage period, inspection windows are required to control refrigeration equipment. Produce should also be placed at the top of one of the walls (Figure 60). Atmospheric composition is crop specific. However, as a general rule the most common combinations are between 2 and 5 percent oxygen and between 3 and 10 percent carbon dioxide (Kader, 1985).

Many crops benefit from atmosphere modification; however, its usage is limited. It is difficult to define products ideal for storing under controlled atmosphere. One of the most important factors is that investment and operating costs should be recovered. The product should be seasonal and have a stable demand during a long marketing period. In addition, the product should have some unique qualities and not be easily substituted by similar products. In other words, it is beneficial to use controlled atmosphere technology when there are no competitor products on the market. This may go some way towards explaining why its usage is limited to specific crops, particularly apples and pears.

Figure 59: **Blackening due to tissue asphyxia of an artichoke head caused by storing in an inadequate atmosphere (photograph by A. Yommi, INTA E.E.A Balcarce).**

Figure 60: **Inspection window in a room with controlled atmosphere.**

Chapter 4

Hygiene and sanitation

4.1 Background

Food safety has always been a major concern of humankind and its origins can be traced back to very early times. The Codex Alimentarius provides an attempt to ensure safe food for everyone and has had worldwide impact. It was developed by FAO and WHO in 1962, after a long preparatory phase. The guidelines and standards set by the regulatory body of the Codex Alimentarius have become widely accepted and have been adopted or taken as a point of reference by most countries (see Appendix). Ensuring food safety is based on the principle of sound science and its proper application. This applies also to fruits and vegetables.

In January 1997, the President of the United States announced the Food Safety Initiative, which promoted a series of measures to be undertaken by government regulatory bodies. During the same year, the *Initiative to Ensure the Safety of Imported and Domestic Fruits and Vegetables* was published. Within this initiative, a series of recommendations or guidelines were put forward that led to the development of Good Agricultural Practices (GAPs) or Good Manufacturing Practices (GMPs). The overall objective is to ensure that fruits or vegetables for consumption, either of domestic or foreign origin, meet the highest quality and safety standards. Although not mandatory, their aim is to reduce microbiological risks by preventing food contamination and to improve the efficacy of control measures if contamination occurs. Different countries worldwide use these guidelines to develop their own GAPs and GMPs (see Appendix).

4.2 Microbiological risk in the production and distribution of fruits and vegetables

The different stages of operations that a product goes through after harvest provide many occasions for contamination besides those that naturally occur in the field. Consumers strongly reject foreign materials on products or inside packages, such as dirt, animal faeces, grease or lubricating oil, human hairs, insects and plant debris. However, because this type of contamination is usually caused by insufficient care in handling, it is relatively easy to detect and to eliminate. A more serious problem is the presence of human pathogens on produce. These may not be visible or detected because of changes in appearance, flavour, colour or other external characteristics. It has been shown that specific pathogens are able to survive on produce sufficiently long to constitute a threat. In fact, many cases of illness related to consumption of produce have been reported (Table 12).

Three types of organisms that can be transported on fruits and vegetables may constitute a risk to human health: virus (e.g. hepatitis A), bacteria (e.g. *Salmonella* spp., *Escherichia coli*, *Shigella* spp.) and parasites (e.g. *Giardia* spp.). Mycotoxins and fungi do not usually constitute a problem because fungi development is usually detected and eliminated well before the formation of mycotoxins. In most cases, bacteria are responsible for illnesses related to the consumption of fruits and vegetables.

Produce can become contaminated through mechanisms that are complex (Figure 61). The best strategy to obtain a safe product is to prevent contamination at various points throughout the production and distribution chain. This includes undertaking certain sanitary treatments and maintaining produce under conditions (mainly temperature) which do not favour the development of microorganisms. This process is known as the "systems approach" (Bracket, 1998) and every step is part of an integrated system. Records and/or documentation of all activities and treatments are required so that a tracing scheme is established. In this way it is possible to identify areas of weaknesses within the system and to take corrective measures. It is necessary to follow the strict written procedures for GAPs and/or GMPs (see Appendix), which are critical factors for the implementation of such a system. This should be combined with systems such as the Hazard Analysis Critical Control Point (HACCP) in order to identify the critical points at which known safety food hazards must be controlled.

This section briefly describes critical factors where risk of microbiological contamination in the production and distribution of fruits and vegetables can affect health and safety. Some preventive measures are proposed which include issues to consider when writing specific GAP and GMP manuals for each crop and growing region.

4.2.1 Before harvest

Some human pathogens are naturally present in the environment. However, faecal deposits (human as well as from domestic and wild animals) are the main source of contamination of produce. Entry is mainly through irrigation or washing water. Microorganisms in surface water (rivers, lakes, etc.) may come from the upstream dumping of untreated municipal wastes. Underground water may also be contaminated

Table 12: **Isolated pathogens in fruits and vegetables and reported illnesses**

Aeromonas spp.	Alfalfa sprouts, asparagus, broccoli, cauliflower, lettuce, pepper
Bacillus cereus	Sprouts
Escherichia coli O157:H7	Cabbage, celery, cilantro, lettuce(*), pineapple, apple cider(*), alfalfa sprouts(*)
Listeria monocytogenes	Bean sprouts, cabbage, cucumber, shredded cabbage(*), potato, radish, mushrooms(*), salads(*), tomatoes and other vegetables
Salmonella spp.	Artichoke, bean sprouts(*), tomato(*), alfalfa sprouts(*), apple cider(*), cauliflower, celery, eggplant, Belgian endives, pepper, cantaloupe(*), watermelon(*), lettuce, radish and several vegetables
Clostridium botulinum	Shredded cabbage(*)
Shigella spp.	Parsley, leafy vegetables, shredded lettuce(*)
Cryptosporidium spp.	Apple cider(*)
Cyclospora spp.	Raspberry(*), basil(*), lettuce(*)
Hepatitis A	Lettuce(*), strawberry(*), frozen strawberry(*)

(*) Reported illnesses. Adapted from Brackett (1998) and Harris (1998).

from septic tanks leaching through soil into aquifers. If only contaminated water is available, underground drip irrigation is the only irrigation system recommended to avoid the contamination of above-ground edible plants (Table 13).

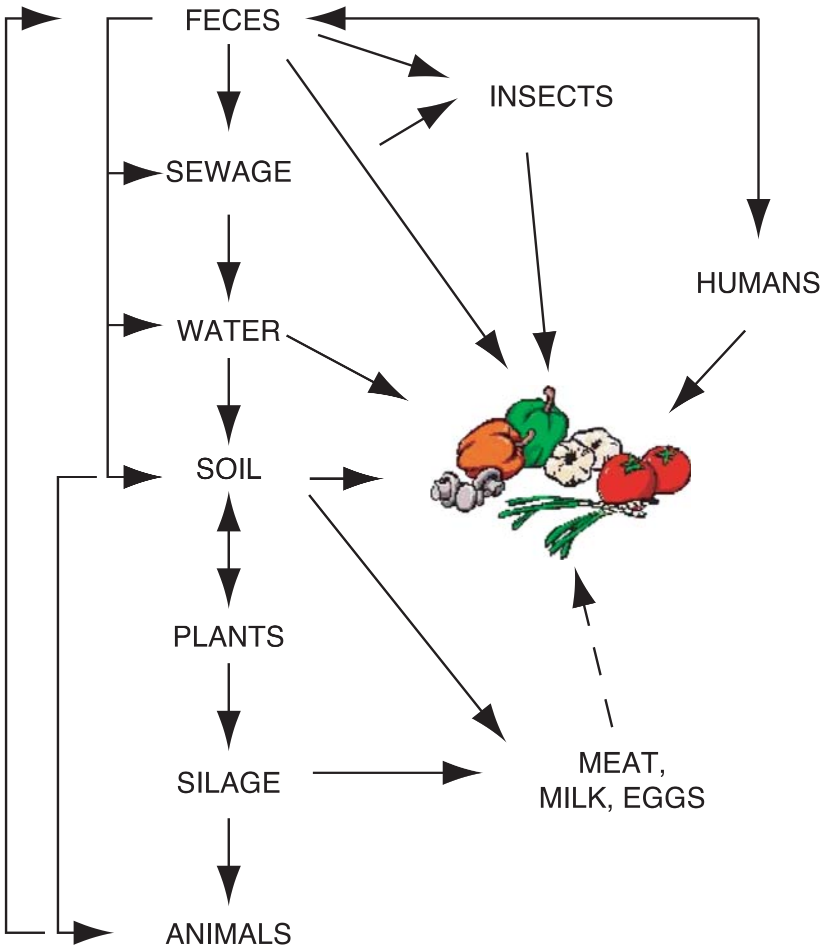

Figure 61: **Mechanisms by which fruit and vegetable can become contaminated with pathogenic microorganisms (adapted from Harris, 1998).**

The main causes of contamination are the use of animal manure or sewage waste as organic fertilizer and the presence of animals in production areas. Manure should be composted aerobically to reach between 60 and 80 °C for a minimum of 15 days. Composting of static piles and earthworms do not guarantee that microorganisms have been inactivated. Wastewater and municipal wastes should only be used if effective disinfecting systems are available.

Table 13: **Potential risks of microbial contamination and recommended preventive measures**

Production step	Risks	Prevention
Production field	Animal fecal contamination	Avoid animal access, either wild, production or even pets.
Fertilizing	Pathogens in organic fertilizers	Use inorganic fertilizers. Proper composting
Irrigation	Pathogens in water	Underground drip irrigation Check microorganisms in water
Harvest	Fecal contamination Pathogens in containers and tools	Personal hygiene. Portable bathrooms. Risk awareness Use plastic bins. Cleaning and disinfecting tools and containes.
Packhouse	Fecal contamination Contaminated water	Personal hygiene. Sanitary facilities. Avoid animal entrance. Eliminate places may harbor rodents. Alternative methods for precooling. Use potable water. Filtration and chlorination of recirculated water. Multiple washing
Storage and transpor-tation	Development of microorganisms on produce	Adequate temperature and relative humidity. Watch conditions inside packaging. Cleaning and disinfection of facilities. Avoid repackaging. Personal hygiene. Do not store or transport with other fresh products. Use new packing materials
Sale	Product contamination	Personal hygiene. Avoid animal access. Sell whole units. Cleaning and disinfection of facilities. Discard garbage daily.

The production and harvest of fruits and vegetables rely heavily on human labour. Other sources of contamination include the hygiene conditions of field workers. First, production fields are usually a long distance from bathrooms and other sanitary facilities for personnel. Secondly, hired teams of migrant labourers temporarily live in the fields with conditions and sanitary practices that are considered unacceptable. In addition to providing portable toilets, it is necessary that all personnel in contact with produce understand the importance of proper hygiene practices for food safety.

The type of product also has an influence on contamination susceptibility. In vegetables that are characterized by low acid content, bacteria tends to dominate, while fruits are mainly colonized by fungi. Crops growing close to the ground like strawberry and leafy vegetables in general are more susceptible to contamination by water, soil, or animals when compared to tree crops. Finally, some chemical constituents of tissues such as organic acids, essential oils, pigments, phytoalexins, etc., have antagonistic effects and provide some form of protection against the development of microorganisms.

As with other handling operations, numerous opportunities exist for contamination during harvest. Wounds and bruises may exude latex and other plant liquids from tissues and provide the substrate for the growth of microorganisms transmitted by hands, tools, clothes, water or containers. Contamination at any point throughout the distribution chain can be exacerbated by the conditions to which the produce is exposed. Temperature is the most important factor to be considered.

4.2.2 Market preparation

The issues highlighted previously on product handling and personal hygiene are equally valid for the preparation of the product for market. However, some additional factors need to be taken into account.

In packinghouses or processing plants, people who are ill or have open wounds should be forbidden from making contact with the produce. Workers should use hairnets and clean outfits when handling the produce.

Street clothes must be left outside the working area and eating or drinking in the packinghouse should be forbidden. Workers should wash their hands daily at the beginning of operations and every time they return to work, particularly after having used restrooms.

The main source of contamination in terms of product preparation for market is probably water, which is essential for washing the product, containers and facilities as well as for dumping and hydrocooling. It is also used for personal hygiene and as a medium for waxes, chemicals, etc.

4.2.2.1 Water disinfection

The most frequent water impurities are suspended materials, microorganisms, organic matter and off-colour and off-odour substances such as minerals and dissolved gases. Municipal water is filtered and treated (normally with low chlorine concentrations) to ensure that it meets the chemical and microbiological requirements for food safety and contact with food. Alternative sources of water must be filtered and sanitized.

Sanitation is necessary to avoid the spread and contamination to other units, even with the use of municipal water. Different methods used for water disinfection include chemical, thermal, ultrasonic waves or irradiation. In postharvest operations, chlorine and its derivatives are the cheapest and most widely used substances to destroy bacteria and fungi in water as well as on the surface of fruits.

Chlorine is an irritant gas with a strong and penetrating odour and has a very strong chemical reaction. At postharvest level, it is used mainly in three different forms: pressurized gas from metal cylinders; calcium hypochlorite (solid); and sodium hypochlorite (liquid), commonly known as "bleach" for household whitening and sanitizing. Chlorine gas is difficult and dangerous to handle and is normally limited to large operations such as municipal water treatment. Calcium hypochlorite is widely used in concentrations of 65 percent but is difficult to dissolve in cold water. Sodium hypochlorite is more expensive than the other two formulations because of its chlorine concentration (5 to 15 percent). However, its easy dosage makes it convenient for small-scale operations.

In aqueous solution, chlorine exists as hypochlorous acid, hypochlorite ion, or as a variation of both, depending on the pH solution: the former predominates in acidic solutions while the latter predominates in alkaline solutions. Germicidal action of hypochlorous acid is about 50 to 80 times higher than hypochlorite. In order to maximize the effect on microorganisms, the pH solution should range between 6.5 and 7.5. Below this range, the hypochlorous form is extremely unstable and tends to escape as a gas resulting in irritation and discomfort to workers. It also becomes extremely corrosive for the equipment. On the other hand, its effectiveness as a sanitizer is significantly reduced above 7.5. To keep pH values within permitted ranges, vinegar is used to acidify while sodium hydroxide is used to alkalinize. Maintenance kits for swimming pools could be used to monitor pH. Chlorine as a gas lowers the pH of the solution while as calcium or sodium hypochlorite the pH increases.

Concentration of active chlorine is expressed in parts per million (ppm). Concentrations of active chlorine in the range of 0.2 to 5 ppm are able to kill most bacteria and fungi present in water. However, in commercial operations higher concentrations are used (100-200 ppm) for washing and hydrocooling. A litre of household bleach (80 g active chlorine/dm^3) in 400 litres of water represents about 200 ppm, and in 800 and 1 600 litres, about 100 and 50 ppm, respectively. It is convenient to start daily operations with low concentrations (100-150 ppm) and to increase the amount of chlorine in solution as water becomes contaminated with dirt and plant debris and an increase in microorganisms occurs.

Quick exposure (around 3 to 5 minutes) is adequate for the purposes of disinfection. However, the temperature of the solution is also important because low temperatures can reduce activity. Another important factor is the extent to which microorganisms develop because their spores are from 10 to 1 000 times more difficult to kill compared with when they are in their vegetative state.

The use of chlorine in fruits and vegetables is banned in some countries because it is possible for it to react with organic matter leading to the formation of chlorate compounds and trihalomethans, which are suspected of being carcinogenic. As a result, the industry is investigating alternative sources of sanitizers.

Ozone is a gas with a strong oxidizing action in concentrations of 0.5-2 ppm. It has been approved for water sanitation; however, it is difficult to apply because reliable methods for monitoring the level of concentrations do not currently exist. In addition, it is only effective within a reduced pH range (6-8) and must be generated in the same place of application. It is dangerous to humans in concentrations higher than 4 ppm and may cause damage to some plant tissues. In spite of these limitations, it is probably the most promising compound to replace chlorine. Ultraviolet light in wavelengths of 250-275 nm can also be used. It is unaffected by water temperature or pH; however, water must be filtered because turbidity reduces its efficacy.

The general management of water is also important. Several washes are much more effective than a single wash. For good cleaning practices: first, undertake an initial wash to eliminate dirt and plant debris; secondly, wash with chlorinated water; and finally, rinse with plain water. Brushing and water agitation increase washing efficiency. Water should be recycled in reverse to the flow of the product, i.e. rinsing waters can be reused for the initial washing. Hydrocooling is one of the most efficient systems for precooling. It is, however, also one of the riskiest in terms of microbial contamination, which can be caused by water infiltration inside fruit. As a result, it is important to consider alternative precooling methods such as forced air.

4.2.2.2 Plant hygiene

Industrial facilities usually follow strict hygiene measures. However, when produce is prepared for the fresh market limited attention is paid to hygiene facilities. This is particularly the case when low cost materials have been used for the construction of the packing shed.

Although other factors need to be taken into account prior to layout and organization, it is important that the packing shed be designed to allow for thorough cleaning procedures. The reception area should be separated from the delivery area. Similarly, “clean areas” or areas where produce is prepared should be separated from areas where produce is received from the field. There should be a clean area where workers can take breaks, change clothes and take care of personal hygiene. This necessitates the availability of hot water, showers and clean restrooms within a clean and comfortable environment.

In addition to the elimination of dust and other impurities, liquid sanitizers should be used to disinfect the facility and equipment, particularly where there is contact with produce. Chlorine-based sanitizers are the most widely used disinfectants. The choice depends on the type of water, pH, cost and the type of equipment. Iodine-based disinfectants (iodophors) are less corrosive to metals than chlorine and are unaffected by organic matter. However, the pH range in which they are effective is quite narrow (2.5-3.5) and, in addition, they may stain surfaces. Quaternary ammonium compounds are widely used for disinfecting floors, walls and aluminium equipment. While effective over a wide pH range, they are not affected by organic matter and are non-corrosive. However, they are expensive and leave residues on surfaces. There are other sanitizers available on the market that can be used in food plants.

Animals of all types, including mammals, birds, reptiles and insects as well as pets, can spread microorganisms with their droppings. Their entry into packing areas should be forbidden. It is necessary to seal crevices and keep doors, windows, and air inlets closed or fitted with insect-proof screens. It is also important to have insect and rodent control programmes, together with approved pesticides, traps and bait. Facilities and the surrounding environment must be kept clean and tidy to prevent the nurturing and harbouring of insects, rodents, reptiles and other animals. Garbage and waste materials should be removed daily.

4.2.3 Storage and transport

In terms of sanitation, there are two potential sources of risk: the contamination by human pathogens and their growth and development, which is enhanced by the favourable conditions created in the packaging environment or storage area. Factors highlighted earlier about hygiene of personnel and facilities are also applicable here. The use of new containers and the elimination of repackaging are important precautionary measures. Also, fruits and vegetables should not be stored or transported with other fresh food items to prevent cross contamination.

The best strategy to prevent the growth and development of human pathogens is to keep produce at recommended storage conditions, particularly temperature. Microorganisms can be divided into three main categories according to their level of adaptation to temperature. They are as follows: 1) psychrotrophic – the ability to grow under refrigerated conditions, although the optimum is ambient temperature (20-30 °C); 2) mesophilic – those that develop best at ambient temperature (20-40 °C) but not under refrigeration and 3) thermophillic – requiring temperatures above 40 °C. The last two do not concern fruits and vegetables for the fresh market but may be present in inadequately processed items. Generally, refrigeration inhibits growth of microorganisms, but psychrotrophics may develop on produce if storage time is too long.

The atmosphere in which a product is stored also influences microbial development. *Clostridium botulinum*, for example, is not a concern when a product is prepared for the fresh market; however, it may develop and produce toxins on tissues with a pH higher than 4.6 and under conditions of low oxygen. It may be present in canned products that have not been adequately pasteurized, but it may also develop under modified atmosphere conditions. It has been reported that this bacterium (Table 12) can cause human poisoning.

4.2.4 Sale

Fruits and vegetables may become contaminated at the point of sale, storage and home preparation. The previous discussions on personal hygiene and prevention of contact with animals are also valid here. The common practice at the retail level of cutting large fruits into portions (pumpkins, watermelons, melons, etc.) should be avoided and refrigeration is recommended for perishable items.

4.3 Final considerations

Fruits and vegetables are microbiologically safer than meat, milk, poultry and other foods. However, during the process of fighting organisms they do not usually undergo a kill step therefore many organisms are not destroyed (by cooking) and are potentially dangerous if contamination exists. It is difficult to estimate how real this potential threat is because it is usually not reported until it becomes serious. As fruits and vegetables are regarded as "healthy food", they are not considered to be the cause of food-related illnesses. Instead, other food eaten during the course of the same day is usually to blame. Available evidence however seems to indicate that this is increasingly becoming a problem, which can be attributed to two main causes. First, there is a trend towards environmentally friendly practices in agriculture, and the use of manure-based organic fertilizers or soil amendments increases the risk of contamination. Secondly, the concentration of supply, particularly through supermarket distribution centres that supply a large number of stores, means that a single case of contamination can have an enormous impact throughout the system.

To obtain high-quality produce with minimum risk levels, the first step is to understand the complexity of microbial contamination and recognize its importance. The examples of good agricultural and manufacturing practices described in these paragraphs may not apply to all fruits and vegetables; however, they may be useful to devise specific preventative measures. With the current level of technology, it is not possible to eliminate this risk; nevertheless it is important to know how to minimize it as much as possible. Preventing microbial contamination of fruits and vegetables is cheaper and more effective than confronting the problem when it occurs. A successful food safety programme requires serious commitment from everyone throughout the food chain from production to consumption. Key factors to be considered are the availability of trained personnel and a system that ensures that there are no missing links in the quality chain as regards contamination prevention.

Many different testing procedures exist for the detection of microorganisms, such as total plate counts (Figure 62) or aerobic plate count. They give an idea of the extent of microbial contamination, but have limited value in terms of assessing food safety. A wide range of microorganisms exists naturally on the surfaces of fruits and vegetables and will colonize a growing medium. However, this does not mean that they are a health hazard. These types of tests are useful for monitoring the hygiene system or evaluating the impact of certain sanitary measures. Detection of *Salmonella* spp., faecal coliforms, *E. coli*, and other pathogens requires specific tests; however, their lack of detection does not mean that the produce is free from other harmful microorganisms. As a result, the best strategy is to minimize the risk and to prevent as much contamination as possible. An important aspect in any programme of good agricultural or manufacturing practices is to have a tracing system because it is possible to identify and to pinpoint quickly problems of contamination. The necessary corrective measures can be undertaken as soon as possible. The short time between harvest and consumption of fruits and vegetables makes it difficult to react in time if an outbreak is detected. In spite of these limitations, keeping records may help to reduce the number of people at risk and should complement all preventive measures described in this section.

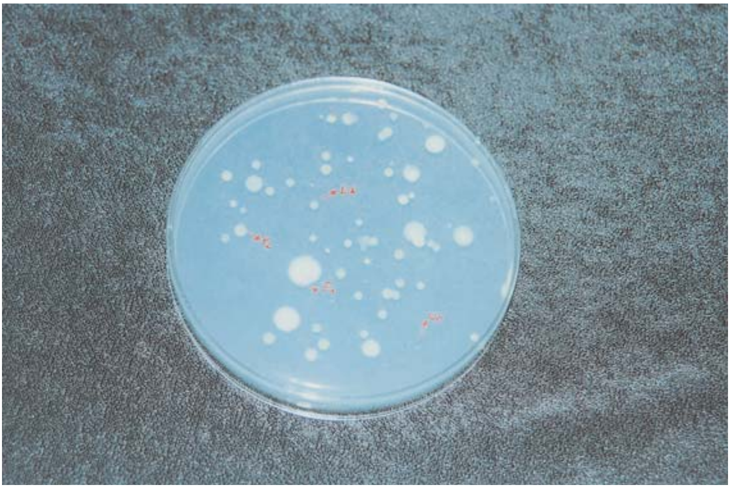

Figure 62: **The total plate count of aerobic colonies on a growing media gives an idea of the degree of contamination.**

Chapter 5

The quality in fruits and vegetables

5.1 What does the consumer demand?

Many publications speak generically of the "consumer" as if a single type existed or as if his/her likes and preferences were perfectly defined. On the contrary, consumption profiles are specific for each country or even region and they vary with sex, age and educational and socioeconomic levels. However, there are universal behaviour patterns and this manual only refers to those characteristics and demands that are common worldwide and that may be useful to understand the average consumer.

In the first place, there is a worldwide tendency towards a greater consumption of fruits and vegetables because of a growing concern for a more balanced diet, with a lower proportion of carbohydrates, fats and oils and a higher proportion of dietary fibre, vitamins and minerals.

Another aspect that deserves attention is the tendency towards simplification in the task of preparing daily meals. In the United States, until the 1960s, the preparation of lunch or dinner required about two hours and was planned in advance. Nowadays, meals are prepared in less than one hour and the menu to be served at dinner begins to be defined after 4 p.m. (Cook, 1998). The expanding availability of processed fruits and vegetables and other readymade foods are partly responsible for this reduction in the time dedicated to cooking. Probably the most significant fact that encourages this tendency is the increasing incorporation of women in full-time work, which reduces their time to buy and to prepare foods but gives them more means to spend money.

Consumption patterns are also influenced by the increasing market segmentation through the expansion in shapes, colours, flavours, ways of preparation and packaging of the product. For example, today at least four different types of tomatoes can be purchased: conventional or beef tomato, extended shelf life, cherry and processing types sold fresh, all of them in different sizes, packages and in some cases colour. There is also an increasing supply of exotic or non-conventional fruits and vegetables, which notably expands the purchase options. For example, in 1981 in a well-supplied supermarket in the United States, there were 133 options of different fruits and vegetables, which increased to 282 in 1993 and to 340 in 1995 (Cook, 1997). Without reaching these levels, the same tendency is observed in the different countries of Latin America and the Caribbean.

Lastly, there is a growing demand for higher external and internal quality. External aspects (presentation, appearance, uniformity, ripeness, and freshness) are the main components in the decision to purchase, which is usually taken when the consumer sees the product exhibited at the sales point (Figure 63). This is particularly important in self-service systems where the product must "self-sell" and if it is not chosen, represents a loss for the retailer. Internal quality (flavour, aroma, texture, nutritional value and absence of biotic and non-biotic contaminants) is linked to aspects that are not generally perceived externally but are equally important to many consumers.

Within a general tendency towards greater consumption and variety, the consumer demands quality in terms of appearance, freshness and presentation as well as nutritional value and safety.

5.2 Definition of quality

The word "quality" comes from the Latin *qualitas*, which means attribute, property or basic nature of an object. However, nowadays it can be defined as the "degree of excellence or superiority" (Kader *et al.,* 1985). Accepting this definition, it can be said that a product is of better quality when it is superior in one or several attributes that are objectively or subjectively valued.

In terms of the service or satisfaction that it produces to consumers, quality could also be defined as the "degree of fulfilment of a number of conditions that determine its acceptance by the consumer". Here a subjective aspect is introduced because different consumers will judge the same product according to their personal preferences.

The destination or use can also determine different criteria for judging quality within the same crop. For example, the tomato for fresh consumption is valued essentially by its uniformity, ripeness and absence of defects, while colour, viscosity, and industrial yield as raw material define the quality for the tomato used for ketchup. It is common to use additional words to define the quality to the specific use such as industrial quality, nutritional quality, export quality and edible quality.

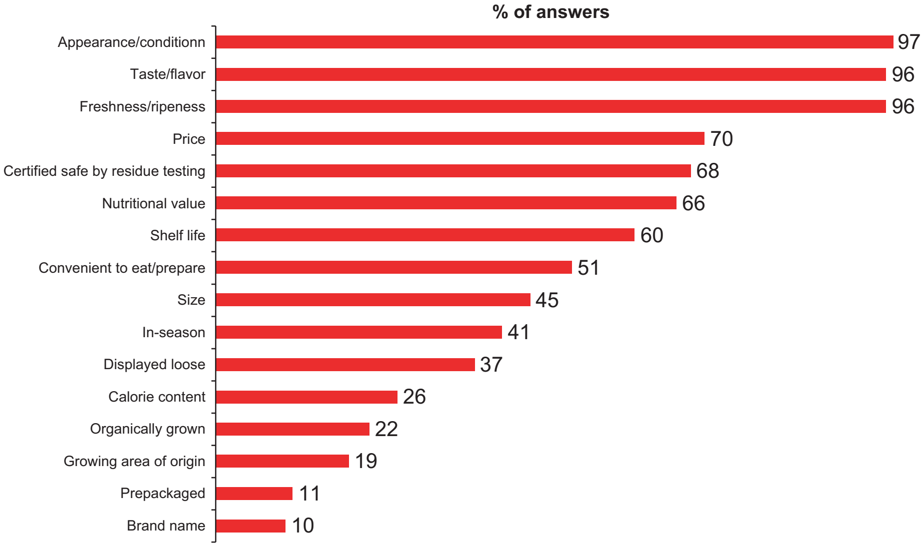

Figure 63: **Percentage of answers by consumers evaluating these visible aspects as extremely or very important (reproduced from Tronstad, 1995).**

5.3 Perception of quality

Quality is a complex perception of many attributes that are simultaneously evaluated by the consumer either objectively or subjectively (Figure 64). The brain processes the information received by sight, smell, and touch and instantly compares or associates it with past experiences or with textures, aromas, and flavours stored in its memory. For example, just by looking at the colour, the consumer knows that a fruit is unripe and that it does not have good flavour, texture or aroma. If colour is not enough to evaluate ripeness, he/she uses the hands to judge firmness or other perceptible characteristics. The aroma is a less used parameter except in those cases where it is directly associated to ripeness like in melon or pineapple. This comparative process does not take place when the consumer sees for the first time an exotic fruit whose characteristics are unknown.

The final evaluation is the perception of the flavour, aroma and texture when the product is consumed and when sensations perceived at the moment of purchase are confirmed. If satisfaction is the result, loyalty is generated. For example, if you discover

APPEARANCE/CONDITION

Shape
Compactness
Uniformity
Defects — *Physical*, *Morphological*, *Physiological*, *Pathological*, *Entomological*

FRESHNESS/RIPENESS

Colour (ripeness)
Size
Gloss
Texture — *Firmness/hardness/softness*, *Crispines*, *Juiciness/succulence*, *Fibrousness*, *Mealiness*

FLAVOUR/TASTE/AROMA

Sweetness - Sourness - Bitterness
Astringency - Volatiles (aroma)
Off-flavours and off-odours

NUTRITIVE VALUE

Carbohydrates (included dietary fibre)
Proteins
Lipids
Vitamins
Minerals
Phytochemicals

SAFETY

Naturals toxicants
Non biotic contaminants
Mycotoxins
Microbial contamination

Figure 64: **Consumer perception of quality.**

that you prefer red apples to green ones, you will continue consuming red apples. It is possible to generate loyalty to commercial brands, presentation forms, packaging, sales places, etc.

Fruits and vegetables are consumed mainly for their nutritive value as well as for the variety of shapes, colours and flavours that make them attractive for food preparation. When they are consumed raw or with very little preparation, the consumer's main concern is that they must be free of biotic or non-biotic contaminants that may affect health.

5.3.1 Components of quality

5.3.1.1 Appearance

Appearance is the first impression that the consumer receives and the most important component of the acceptance and eventually of the purchase decision. Different studies indicate that almost 40 percent of the consumers decide what to buy inside the supermarket. Shape is not a decisive aspect of quality, except in cases of deformation or morphological defects. In some instances, shape is a ripeness index and therefore an indication of flavour such as in the case of the "full cheek" in mango or the "finger" angularity in bananas.

Compactness is the most relevant feature in species where the inflorescence is the marketable part such as broccoli and cauliflower, and in those species that form "heads" such as lettuce, cabbage and endive. In general, it is not associated to their organoleptic characteristics but rather is an indicator of the degree of development at harvest. Open inflorescences indicate that they were picked too late while non-compact "heads" are the consequence of a premature harvest. To a certain extent, compactness is also an indicator of freshness because it decreases with dehydration.

Uniformity is a concept applied to all the components of quality (size, form, colour, ripeness, compactness, etc.). For the consumer it is a relevant feature that indicates that someone who knows the product has already selected and separated it into categories based on the official standards of quality. It is so important that selecting products for uniformity is the main activity of market preparation.

In many cases, internal or external defects do not affect product excellence, but the consumer rejects them because the absence of defects is one of the main components of appearance and therefore of the primary decision to purchase. Different factors during growth (climate, irrigation, soil, variety, fertilization, etc.) can lead to morphological or physiological defects. Some examples of morphological defects are "doubles" in cherries, root ramifications in carrots, "catface" tomatoes, "knobby" tubers and "hollow heart" potatoes. Tip burn on leafy vegetables and black heart in celery caused by calcium deficiencies as well as internal rot in various species because of boron deficiencies are examples of physiological defects. More serious are those physical and physiological defects that originate during or after preparation for the fresh market and that show up at the retail or consumer level. Physical defects include mechanical damages, bruises and wounds that occur during the handling of the product (see Chapter 1) and which are the entrance doors to most pathogens that cause postharvest rot. Chilling injury, ethylene effects and sprouting and rooting are physiological responses to inadequate storage conditions.

Freshness and ripeness are part of the appearance and they have components of their own. They are also indicative of the expected flavour and aroma when products are consumed. "Freshness" is the condition of being fresh or as close to harvest as possible. Freshness is also used to describe vegetables harvested at the point of maximum organoleptic quality characterized by the greatest turgidity, colour, flavour and crispness. "Ripeness" is a concept used for fruits that refers to the point of maximum edible quality. In many cases, however, ripeness is reached at the level of sales or consumption because, in most commercial operations, fruits are harvested slightly immature. For example, fruits stored in controlled atmosphere reach their edible quality after leaving the store room, several months after harvest.

Within the parameters for defining freshness and ripeness, colour, both in its intensity and uniformity, is the external aspect most easily evaluated by the consumer. It is decisive in those products like leafy vegetables or unripe fruits such as cucumber, snap beans and others where an intense green colour is associated with freshness and pale green or yellowing to senescence. Colour is also an indicator of ripeness and is very important in those fruits where no substantial changes take place after harvest (non-climacteric fruits), such as citrus, pepper, eggplant, and cucurbits in general. In fruits that suffer changes after harvest (climacteric), colour is less decisive and basically indicates the degree of ripeness, such as tomato, pear and banana.

Consumers give size a certain importance (Figure 63) and at equivalent quality, intermediate sizes are preferred. For fruits that are naturally large, such as pumpkins, watermelons and melons, there is a strongly defined trend towards sizes that can be consumed by a family (1-2 kg) in a relatively short period (one week). Size is one of the main indicators of the moment of harvest (Chapter 1) and in many cases it is directly associated to other aspects of quality such as flavour or texture. Such is the case for zucchinis, peas, haricot beans and miniature vegetables in general where consumers particularly value small sizes.

Gloss enhances the colour of most products, but it is particularly valued in species such as apples, peppers, eggplant, tomatoes, grapes, plums and cherries to such a point that many of them are waxed and polished to improve their shine. In vegetables, gloss is associated in a certain way to turgidity: a brilliant green is one of the indicators of freshness. It can also be used as a harvest index for eggplants, cucumbers, squash and other fruits that are harvested unripe and where the decrease in shine indicates that they have developed too much and have lost part of their characteristics of flavour and texture. On the contrary, for melon, avocado and other species, gloss is indicative that they have reached ripeness for harvest.

Different sensations perceived by humans are included within the definition of texture. Thus, firmness is perceived with the hands, and the type of surface (hairy, waxy, smooth, rough, etc.) is perceived with the hands and lips. Teeth determine the rigidity of the structure that has been chewed while the tongue and the rest of the mouth cavity detect the type of particles that are crushed by teeth (soft, creamy, dry, juicy, etc.). Also the ears contribute to the sensation of texture, for example, the noises generated when chewing in those species where crispness is an important aspect (Wills *et al.,* 1981).

Together with flavour and aroma, texture constitutes eating quality. An overripe tomato, for example, is mainly rejected for softening and not because important changes in the flavour or aroma have taken place. Although texture is decisive for the quality of some fruits and vegetables, in others it has relative importance. In terms of texture, each product is valued differently: for firmness (tomato, pepper), the absence of fibres (asparagus, globe artichoke), softness (banana), juiciness (plum, pear, citrus) and crispness (celery, carrot, apple).

Firmness and colour are the main parameters used to estimate the degree of ripeness of fruit. Ripeness initially improves and softens fruit texture and, together with the changes in flavour and colour, brings the fruit to reach its maximum edible quality. However, as this process continues, overripeness takes place, which leads finally to tissue disorganization and decay of the product. Firmness is used mainly as a harvest index and it is measured with instruments (Figure 12) that register the force necessary for a certain deformation or resistance to the penetration of a piston of known dimensions.

Juiciness is the sensation of liquid spilling inside the mouth as tissues are chewed. The juice content of many fruits increases as they ripen on the plant. For citrus fruits the regulated minimum juice content is as follows: 30 percent for navel oranges; 35 percent for grapefruit and other oranges; 25 percent for lemons; 33 percent for mandarins and 40 percent for clementines (Thompson, 1996).

5.3.1.2 Flavour

Flavour is the combination of the sensations perceived by the tongue (taste) and by the nose (aromas) (Wills *et al.,* 1981). Although these sensations can be perfectly separated one from the other, as the sensitive receptors are so close, simultaneously with the act of bringing the product near the mouth, of biting, chewing and tasting, we are perceiving the aromas, particularly those that are liberated with the crushing of tissues. It is also possible, however, that certain external aspects (particularly ripeness) anticipate the flavour that should be expected when consuming the product. The human being has stored in his/her memory an enormous quantity of different tastes and aromas and, if a product was eaten previously, is able to recognize the product without seeing it.

For fruits and vegetables, taste is usually expressed in terms of the combination of sweet and sour principles that are an indication of ripeness and eating quality. The content of soluble solids is a good estimate of total sugar content, and many fruits should have a minimum content of solids to be harvested (Table 14). Organic acids (citric, malic, oxalic, tartaric) are the other important components of taste, particularly in their relationship with soluble solids. As the fruit ripens the organic acids tend to diminish and so the relationship with the soluble solids tends to increase. Titratable acidity is the form of expressing acidity. The soluble solids/titratable acidity relationship is a denominated *ratio* and it is essentially used in citrus where it is a function of the species and of the variety. Its value is 8 for mandarins, navel oranges and hybrids, 7 for other type of oranges, and 5.5 for grapefruits (Lacey *et al.,* 2000).

Astringency (sensation of loss of lubrication in the mouth) and bitter tastes are caused by different compounds, which are not frequent and when they do exist, usually diminish with ripening. In those cases in which they appear naturally and represent a disadvantage, they have been eliminated through breeding programmes.

There are specific compounds that characterize certain species or a group of them, for example, pungency in peppers denominated "hot" is basically determined by the capsaicin content and four other structurally similar compounds. There are also cases in which enzymes and substrata responsible for the taste are compartmentalized in healthy

Table 14: **Recommended minimum soluble solid content at harvest**

Apple	10,5-12,5
Apricot	10
Blueberries	10
Cherry	14-16
Grape	14-17,5
Grapefruit	8
Kiwifruit	14
Mango	8
Mandarin	8
Melon	10-12
Nectarine	10
Orange	8
Papaya	11,5
Peach	10
Pear	13
Persimmon	18
Pineapple	12
Plum	12
Pomegranate	17
Raspberry	8
Strawberry	7
Watermelon	10

Source: Kader, 1998.

tissues and only come in contact by cutting, chewing or crushing. This is the case of pungency in garlic and onion and also of the taste of raw cucumber. Cooking these vegetables whole prevents these reactions and the resulting taste is different.

There is a correlation between dry matter content and organoleptic characteristics mainly used by the industry. In general, a higher content of solids means higher industrial yield and taste. This is particularly important in dehydrated products. For potatoes, a higher content of dry matter (measured as specific gravity) is associated with a better cooking quality. For the fresh market, however, dry matter content is not used as an indicator of the time of harvest and/or organoleptic quality, except in the case of avocado where there is a close correlation with the oil content. Depending on the variety considered, avocados with a dry matter content lower than 21-23 percent should not be marketed (McCarthy, 2000).

The aroma of fruits and vegetables is attributable to the human perception of numerous volatile substances. Refrigerated fruits and vegetables are less aromatic because volatile liberation diminishes with temperature. As in the case of taste, many aromas are liberated when tissues lose their integrity.

5.3.1.3 Nutritive value

From the point of view of nutrition, fruits and vegetables are insufficient to satisfy daily requirements, essentially because of their low content of dry matter. They have a high content of water and are low in carbohydrates (except for sweet potatoes, potatoes, cassava, and other underground organs), proteins (except for legumes and some crucifers) and lipids (except avocados), but, in general, they are a good source of minerals and vitamins. Different countries have made tables of recommended daily consumption, the best known being probably the U.S.R.D.A. (United States Recommended Daily Allowances) as shown in Table 15. These tables are only for reference and they indicate the capacity of foods to satisfy the daily needs for certain nutrients. The actual content of nutrients is affected by the conditions of cultivation, varieties, climate and preparation.

Dietary fibre can be defined as the vegetable portion that cannot be degraded by the enzymes of the human digestive tract although its components are anaerobically metabolized in variable proportions by the colon microflora. The optimum daily intake for a healthy adult is between 25 and 30 grams and the contribution of certain fruits and vegetables to the minimum needs is shown in Table 15.

The discovery that certain foods have biologically active compounds beneficial to health beyond basic nutrition opened a new stage in nutrition science. These compounds or their metabolites that have been denominated “functional” help to prevent diseases such as cancer and have a protective effect on cardiovascular problems. They are also neutralizers of free radicals, reduce cholesterol and hypertension and prevent thrombosis. Those foods that contain them are also called “functional” although other names such as “pharmafoods”, “nutraceuticals” and others have been proposed. As most of these compounds are of plant origin, many authors call them phytochemicals.
Fruits and vegetables are rich in phytochemicals such as: terpenes (carotenoids in yellow, orange and red fruits and limonoids in citrus); phenols (blue, red and purple colours of cherries, grapes, eggplant, berries, apples and plums); lignans (broccoli); and

Table 15: **Content of essential nutrients (* = good; X = very good; XX = excellent; ■ = exceed daily requirements)**

SPECIES	Vitamin A	Vitamin C	Thiamin	Riboflavin	Niacin	Calcium	Iron	Fiber
Swiss chard	X	*						
Artichoke		*						XX
Pineapple		X						
Celery		*						X
Blueberry		X						*
Cranberry		*						*
Pea		XX	*					*
Banana								X
Sweet potato	■	XX		*				*
Broccoli	*	■		*				■
Carambola	*	XX						*
Onion		*						X
Plum		*						
Cauliflower		■						XX
Kohlrabi		XX						
Kale	■	■						
Snapbeans		*						
Cherimoya		XX				*	*	XX
Parsnip		*						*
Sweet corn			*					
Apricot	XX	*						
Date								*
Belgian endive	*							
Asparagus		*	*					XX
Spinach	XX	X					*	
Raspberries		XX						XX
Strawberry		■						
Fig						X	*	XX
Mushrooms				*				
Kiwi		■						XX
Lettuce Iceberg								*
Lettuce Romaine	X	X						
Lime		X						
Lemon		XX						
Mango	■	XX						*
Apple		*						X
Cantaloupe ripe	■	■						*

Table 15: **(cont.)**

SPECIES	Vitamin A	Vitamin C	Thiamin	Riboflavin	Niacin	Calcium	Iron	Fiber
Melon Honeydew		XX						*
Blackberry		X						X
Turnip		*						
Orange Navel		■						
Orange Valencia		XX						
Nectarine		*						
Okra	*	*						
Avocado		*						XX
Potato	*	XX	*	*	*		*	X
Papaya		■			*			X
Cucumber								*
Pear		*						X
Pepper		■						
Grapefruit		XX						
Leek		*						
Radish		X						
Beet (topped)		*						
Cabbage	XX	■						XX
Cabbage (red)		XX						
Cabbage Savoy	*	X						
Brussels sprouts	*	■						*
Rutabaga		X						
Watermelon	X	XX	X					*
Tomato	*	XX						
Jerusalem artichoke			*					
Carrot	■						*	
Pumpkin	X	*						
Pumpkin acorn		X	*					*
Pumpkin Butternut	■	XX						*
Pumpkin Hubbard	■	*						*

Source: The Packer, 1996; Produce Marketing Association, 2000.

thiols (sulphur compounds present in garlic, onion, leek and other alliums and cabbages and other crucifers in general).

5.3.1.4 Safety

Fruits and vegetables should be fresh, nutritive and attractive in their appearance and presentation. Their consumption should not put health at risk. The consumer has no way to detect the presence of dangerous substances and therefore he/she depends entirely on the seriousness and responsibility of all the members of the production and distribution chain. As a logical result the consumer must place his trust in them, in addition to the usual precautions of washing, peeling and/or cooking the product before consuming it. However, this trust is very volatile and any suspicion about safety has a tremendous impact at the consumer level. Among the most relevant examples is the epidemic of cholera in the 1990s in Latin America that reduced the consumption of vegetables in many countries of the region for almost one year. Another example may be the two grapes with dangerous residues detected in the 1980s in an entrance port of the United States, which severely affected Chilean exports. Also about that time, the Alar (daminozide, a growth regulator used to control fruit set) scare considerably reduced the consumption of apples in the United States.

Food safety is the absence of substances dangerous for health, and the presence of pesticide residues on fruits and vegetables has been the main concern for consumers. However, there are many other contaminants potentially as dangerous such as the presence of pathogenic microorganisms, mycotoxins, heavy metals and others.

As fruits and vegetables are consumed fresh and many times are not peeled, all pathogenic organisms that are carried on their surface constitute a potential danger. The hygienic and sanitary measures necessary to reduce the food risk have already been described in the previous chapter. Bacteria, like *Shigella* spp., *Salmonella* spp., *Aeromonas* spp., *Escherichia coli*, *Listeria monocytogenes* and the toxins produced by *Clostridium botulinum* and others, have been identified as responsible for illnesses associated with the consumption of fruits and vegetables. The hepatitis A virus has been detected on fresh produce as well as parasites like *Entomoeba histolyca*, and *Giardia lamblia* (Table 12).

Agrochemicals are one of the tools that man has used to satisfy the growing need for food. They are the herbicides, insecticides, fungicides, fumigants, rodenticides, growth regulators, waxes, disinfectants, additives and all other products of a chemical nature used during production or postharvest handling. Their residues have always been a major concern, although advances in chemistry and biochemistry, better understanding of ecology as well as pests and diseases and the growing use of non-chemical control methods have made the present world a much safer place. The agrochemicals used today are less toxic and persistent and their degradation products are generally innocuous. Better laboratory methods have been developed for their detection and there is a greater consciousness about their use, waiting times, doses, etc.

Each country has its own legislation in terms of the Maximum Residue Levels (MRLs) within the framework of the Codex Alimentarius Commission or other international organizations. An MRL or tolerance is the maximum concentration of pesticide residue allowed resulting from its application according to correct agricultural practices.

Agrochemical use should be within the framework of the Good Agricultural Practices to guarantee maximum safety and to minimize risks to consumers' health. Specific products should be used to control pests or diseases. The manufacturer's indications should be followed carefully, particularly those referring to crops on which they can be used, as well as minimum waiting times between application and harvest.

Other health hazards include, for example, the presence of nitrates in leafy vegetables, oxalates in some species and heavy metals accumulation, particularly when household waste is used as fertilizer or an organic amendment. Some toxicity may exist in some natural compounds produced by the crop itself or by the fungi (mycotoxins) that colonize the surface of the product.

5.4 Obtaining a product of quality

Producing a quality product begins well before planting the seed. Soil selection and preparation, its fertility and irrigation potential, weed control and crop rotations, variety selection and other decisions have an influence on the quality of the product. In the same way, quality is affected by the climatic conditions during the growing period, as well as irrigation, fertilization, control of pests and diseases and other cultural practices. Harvest is the end of cultivation and the beginning of postharvest actions during which preparation for the market, distribution and sale take place.

Fruits and vegetables are highly perishable products that demand water and nutrients before being detached from the mother plant. Once harvested, however, they depend on their reserves to continue living. Respiration, transpiration and the continuous changes taking place determine the internal and external quality. Deterioration rates depend on the type of product, growing conditions and other factors, but mainly on the conditions in which the produce is maintained after harvest, such as temperature, relative humidity, movement and composition of the air. Postharvest changes can only be delayed within certain limits and thus preparation for the fresh market should be quick and efficiently performed in order to avoid quality losses.

Besides natural deterioration and physiological and mechanical injuries already described in previous chapters, rot is also responsible for loss of quality. Postharvest losses caused by microorganisms can be severe, particularly in warm climates with a high relative humidity. Rotting produce contaminates the rest and under these conditions ethylene production is stimulated accelerating the rate of deterioration.

Most of the fungi and bacteria that attack fruits and vegetables after harvest are weak pathogens and they mainly invade tissues through wounds (Wills *et al.,* 1981). Injuries produced during handling provide numerous entrance routes for these pathogens, although some of them are able to invade healthy products. Unripe fruits are usually more resistant to pathogen attack. It is also possible that infection occurring at the immature stage shows up later, when the natural defences are weakened by the ripening process (Dennis, 1987). A good disease control programme at field level reduces the source of inoculum and the risks of infections after harvest, facilitating the control of postharvest diseases. Also, careful handling during harvest and packing operations reduces the physical damage that facilitates the establishment of microorganisms. Temperature control is one of the main tools used to control postharvest diseases because it diminishes the metabolic activity of the microorganisms and keeps the natural defences of the product high by reducing the rate of the ripening process. The control of relative humidity to avoid, in particular, the condensation of water on the product and to maintain controlled atmosphere is also useful in the control of postharvest diseases.

5.5 Towards total quality in fruits and vegetables

The concept of quality as a way to differentiate products has been recognized for years. As local or regional trade internationalizes, quality consolidates as the main competitive tool for excellence, reinforcing the need to establish standards to separate quality into categories or degrees and to define the limits of allowed defects. Nowadays, domestic and international trade of fruits and vegetables is regulated by quality standards in most countries, providing a common language among the different participants of the production-commercialization-consumption chain. Standards are also the legal framework used to settle commercial disputes and are useful as a basis for reporting on market prices, which can be compared only with the same quality category.

The quality system established by the standards is known as "inspection for quality" (Table 16) where representative samples at the final stage of preparation for the market should fulfil the specified limits and their tolerances. Although it is easy to apply, this quality system has at least two major disadvantages. It is not totally adaptable for highly perishable products where quality varies continually, and its application does not improve the quality of the product, it only separates in degrees the quality that comes from the field.

At the same time that quality standards were developed and applied, new ideas began to be conceived by industry. First of all, it became evident that to improve quality a systematic and preventive approach was much more effective and economic than the elimination of faulty units at the end of the line, when production and packaging had already taken place. Secondly, it became clear that the quality concept extends beyond the product itself because it is affected by the systems and procedures involved in the production and preparation for the market. Finally, the consumer's opinion began to be more and more important. It is no longer sufficient for a product to be technically perfect and to be produced in an economically profitable way, it is also necessary to satisfy the consumer's expectations of quality.

The application of statistics to control the variability of the different units in the production lines gave birth to the system called "quality control" or "statistical quality control", which was adopted by most manufacturing companies in the first half of the twentieth century. This method or system essentially provides the analytic tools for monitoring the production process and for taking measures when variability exceeds certain limits considered as normal. Its application improves the quality of the process contributing greatly to improve the quality of the product. They are tools that can be applied at the level of the fruit and vegetable packinghouse.

This system was transferred to Japan after World War II where it evolved into what today is known as "total quality management" (TQM) or simply "total quality". Total quality is today the most complete conceptual framework to assure the quality to which each person or activity within the production process is committed, aiming at zero defects and customer's complete satisfaction, even going beyond his/her expectations. At the same time that TQM was developed, the concept of "quality assurance" was coined in Europe. Its scope is slightly narrower than TQM, but a lot easier to implement

Table 16: **Comparison of the main quality systems**

Aspects	Quality inspection	Quality assurance	Total quality
System	Reactive	Preventive	Preventive
Quality is	A control procedure at the end of the process	The objective of an explicit policy	A philosophy
Application of regulations	Only the mandatory ones (Standards)	Mandatory + voluntary ones as ISO, HACCP	Mandatory + voluntary of own design
Quality is based on	The final product	The organization	Human resources
Quality control is performed by	A quality laboratory	Quality management level	All
Documentation on processes and methods	No	Yes	Yes
Internal auditing	No	Yes	Yes
Certification of conformity	No	Yes	Not necessary

and probably better adapted to fruit and vegetables. It is defined as all those planned and systematized actions necessary to guarantee that the product or service will satisfy the requirements of quality. It usually requires the fulfilment of certain rules, protocols, or standards developed specifically and certification by an independent company authorized to grant it. The ISO system is probably the best known and within it the series 9000.

It is also appropriate to mention the HACCP (Hazard Analysis Critical Control Points) system, designed specifically to guarantee that food is not exposed to any type of contamination that could put health at risk. Today, this method is recognized internationally as the logical and scientific tool for all food quality systems. It is also preventive in nature and the key element is the identification of the critical points within the process, where quality should be controlled to prevent, eliminate or reduce to acceptable levels all possible safety risks. The HACCP system is required today in the United States and other countries to import meat, fish, eggs and other foods. Up to now, it is not required for fruits and vegetables, although different export countries are already implementing it to assure a superior quality of their products. The logic of the HACCP can be applied to the detection of other defects of quality.

Although all these systems have their origin in industry, their application extends to other sectors. Agriculture, and particularly the production of fruits and vegetables, is now incorporating many of the methods and ideas conceived by the industrial sector because the basic principles are not only applicable but also recommendable for highly perishable products where quality deteriorates quickly. Several export companies have implemented the HACCP together with the ISO 9002 certification, which guarantees food safety within a system of quality assurance. A key concept is that quality systems are not mutually exclusive but rather they overlap, widening the application approach, extending beyond the product itself and embracing the preparation process, inputs, suppliers and intermediaries, besides the incorporation of the feedback from the client or consumer for its continuous improvement.

The basic principles of total quality can be summarized in the following way:

- the consumer is always first;
- each operation is part of a process;
- quality improvement never ends;
- quality is made, not controlled;
- prevention of quality problems is made through planning;
- the desired product should be obtained at the desired moment;
- postharvest handling should be appropriate to reach the desired market under the desired conditions.

Chapter 6

Selling fruits and vegetables

6.1 Understanding the consumer

Buyer motivations are quite complex and vary according to gender, age, and cultural, ethnical and regional aspects. The previous chapter showed that consumer attitudes do not follow a uniform pattern. The Inter-professional Technical Centre for Fruits and Vegetables (Laborde *et al.,*1993) identifies three different types of group behaviour patterns. The first group comprises consumers with a basic attitude. They prefer traditional cooking and buy generic and undifferentiated fruits and vegetables. The second group seeks quality differentiation, for example, organic or quality certified products, commercial brands, labels of certification of origin or regional produce that is differentiated. Convenience consumers belong to the third group. They are looking for fast and simple ways to prepare meals and therefore prefer prepared salads, pre-cooked products, pre-packaged items and frozen, canned and ready-to-eat produce.

There are other factors that also influence buying decisions. The main objective of buying is to obtain satisfaction. For fruits and vegetables, this means being able to meet nutritional requirements and to enjoy different tastes, textures, colours and aromas. Tangible quality attributes, such as uniformity, freshness, quality, colour, ripeness and packaging, affect appearance and make produce more appealing or attractive compared with similar products. Intangible quality attributes, such as quality, environmentally friendly production techniques, brand reputation and image of the supplier, also influence buying decisions.

Distribution of produce to consumers can be undertaken either indirectly or directly. In the former case, intermediaries (retailers, wholesalers, brokers, etc.) are responsible for conveying consumer preferences to producers, who prepare the produce to satisfy this demand. On the other hand, selling directly provides farmers with the opportunity to explore the complex range of consumer behaviour and to innovate by developing new alternatives.

6.2 Non-direct marketing

The fruit and vegetable sector comprises numerous small-scale farmers with small plots of land in different production areas around the country. They are often located in areas distant from the main markets, which is the main reason why produce is distributed indirectly to consumers through middlemen and markets. Different commercial agreements and relationships exist between buyers and sellers. Prices normally depend on the volume and quality of produce supplied.

The most common type of marketing channel is probably the terminal wholesale market. Produce supplied from different growing areas is assembled and sold through intermediaries (wholesalers, distributors, importers, etc.) to retailers, food service companies, supermarket chains and smaller regional markets. The main advantage of terminal markets is that the high concentration of supply and demand created by larger volumes establishes greater competition. Another benefit is the fixing of reference prices for the produce traded. Fruits and vegetables should be packaged according to market handling and transport methods. In many cases palletization is required. Wholesalers either buy the produce outright or sell it on a commission basis.

Producers located close to wholesale markets may rent space on a daily basis to sell their produce. Although the high concentration of buyers is beneficial, they often lack bargaining power because of their small volume of produce.

Other alternatives to selling in wholesale markets include selling to collectors, truck drivers, shippers, packers and agents. Local sales to retail outlets (including supermarkets) provide another alternative. Purchasing directly from producers rather than through wholesalers provides some additional benefits, such as freshness, price or specific products with special characteristics. However, high volumes required by supermarket chains may exclude small-scale farmers as suppliers.

Other methods to gain access to large markets include collecting produce from several producers through a cooperative and selling to individual packinghouses. Benefits include uniformity of quality and packaging, reduced costs and the opportunity to hire marketing specialists to increase sales and profitability.

6.3 Direct marketing

Direct marketing is the sale of produce by the farmer directly to the consumer. Different studies show that many consumers prefer direct contact with the producer/seller compared with an impersonal service, although the latter in some cases is more efficient. Direct sales to consumers provide the opportunity to reduce marketing costs and to add value to the product. In this way, the profit margin is increased. Producers need to become aware of existing marketing tools in order to maximize sales.

6.3.1 The retail outlet

In most cities municipal ordinances regulate places and areas where fruit and vegetable retail outlets can operate. The main factors to consider when selecting a location are good visibility, accessibility and proximity to buyers. Street or road crossings, areas near shopping centres or any other areas that attract many people are good locations for produce sales outlets. Some municipalities give permission to place exhibits on sidewalks to attract customers (Figure 65) provided they do not interfere with normal pedestrian traffic.

Figure 65: **Street or road crossings are the best places for a permanent produce outlet. Sidewalk exhibits increase visibility and attract customers but they must not interfere with pedestrian circulation.**

6.3.1.1 Municipal regulations outlet

Municipalities are autonomous and can make their own regulations for the location and operation of fruit and vegetable retail outlets.

6.3.1.2 Layout and organization of a produce outlet

Although many customers have a written or mental list of fruits and vegetables they intend to buy, most buying decisions are made inside the store. The layout and organization of the retail store may help customers to make purchases thereby increasing sales. Traditional personal service and the self-service system are the main types of marketing methods, and in many cases a combination of both are offered.

Many customers prefer the traditional system because personal interaction increases buyer confidence. Loyalty can also be built provided good quality, freshness and reasonable prices are combined with good service and friendliness. The image presented by sales staff is important to customers because they tend to think that people who take care of themselves also take an interest in the produce sold in the store. Sales staff must be courteous and friendly to the customers. There are several drawbacks to traditional personal selling. It is not appropriate for customers who are in a hurry and some sales are lost because serving customers requires additional time.

The self-service system requires an attractive display of goods and a good plan for space allocation of the items for sale. This is important because produce that is not visible or attractively presented is hard to sell. Information about varieties and prices should be clearly legible. Customers should be able to weigh produce or select pre-packaged products that have been pre-weighed and labelled. This marketing method is ideal for people who prefer rapid service and prefer to choose size, ripeness, quantity and quality according to their own purchasing criteria.

The main factors to consider for increasing sales in a self-service outlet are accessibility, visibility and easy flow of circulation. Accessibility is a physical and psychological concept. Produce piled up high, displayed in an untidy way or difficult to reach (Figure 66) may have a negative impact on sales. Consumers also become confused and lose time looking for goods. Ease of circulation makes shopping more convenient, particularly if trolleys can be used. As previously mentioned, visibility is a key factor in determining whether a product can be sold.

Merchandising techniques are important to increase the visibility of the product. From a distance of 2 meters, an average person sees an area starting at 0.8 meters from the floor and up to 2 meters high and about 2 to 3 meters wide. Visibility decreases dra-

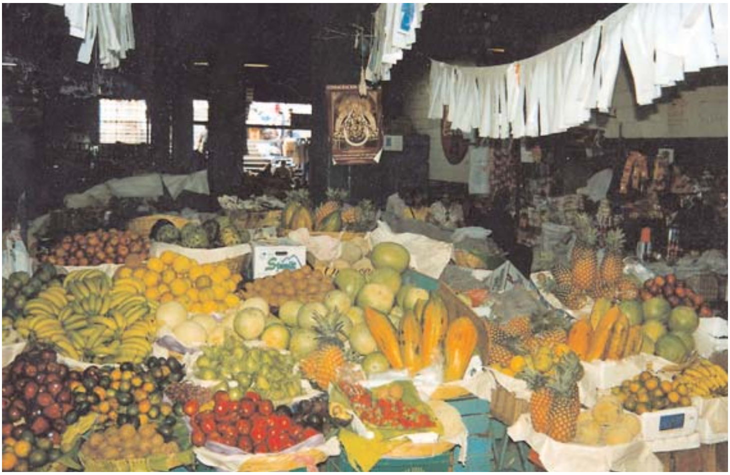

Figure 66: **A display that is disorganized and hard to reach confuses customers and they lose time looking for goods.**

matically outside the indicated area. A minimum area of 0.3 m wide per item is required for good visibility (Figure 67). Large products like watermelons, melons and pumpkins require more space. Special allocation and large displays like islands in the middle of the aisles can be used to draw attention for quick sales (Figure 68). Slanted shelves (30-45°) and mirrors can be used to enhance product presentation (Figure 69). Refrigerated shelves should be used for highly perishable crops (Figure 70).

6.3.1.3 Strategies for maximizing sales

As a rule a wide range of products should be on offer because, as mentioned earlier, most buying decisions take place in the store. A relatively well-supplied produce store should carry at least 20 different fruits and 30 different vegetables. Product choice is not only about the range of crops on offer, but also about the different varieties, colours and types of packaging. Although there are no fixed rules, the proportion of fruits and vegetables on offer should be more or less equal. Vegetables during the summer months should be increased while the opposite should occur during the winter.

The quantity and type of fruits and vegetables for sale varies in each country. However, as a general rule, produce can be divided into two groups. "Basic" refers to bulk produce sales and is demanded by all types of consumers. "Specific" refers to those destined for certain niche markets (Laborde *et al.,*1993).

Figure 67: **Each item for sale occupies shelf space area according to its individual size and the marketing strategy used.**

Figure 68: **Large items require more shelf space. Special allocation and large aisle displays can be used to draw attention for quick sales.**

Figure 69: **Mirrors enhance products and increase their visibility.**

Basic products can be divided into the following categories: permanent – available on shelves year round, for example, apples, tomatoes, potatoes, lettuce and carrots; seasonal – available only during certain months of the year, for example, peaches, nectarines and melons; and minor produce such as garlic, parsley and radishes. Specific categories are: exotics – mainly of tropical origin such as pineapple, mangoes and coconut; off-season crops – in many cases originating from other countries; mushrooms; ready made salads; aromatic herbs; those of a specific quality such as quality certified products labelled with certification or origin or regional differentiated produce; organic and fresh-cut or ready to eat products (Laborde, et al. 1993).

There are many different ways to display produce and some may be highly effective. The most common practice is to place contrasting colours next to one another in order to create a contrast of different coloured commodities, for example, red tomatoes next to green cucumbers, or violet and white eggplants. Another method includes mixing and matching products that are often sold together such as tomato and lettuce for salads, bananas with other fruits for making fruit salads. Less common is the grouping of similar products such as tubers and roots (Figure 71).

6.3.2 Street selling

While street selling is frequently seen in developing countries, generally most municipalities do not allow it. First of all, there are public health and hygiene considerations,

Figure 70: **Refrigerated displays should be reserved for highly perishable items.**

and as an activity it generates off-odours and insect and rodent proliferation. Secondly it constitutes unfair competition for established outlets that are periodically inspected for observation of health and tax regulations.

Ambulatory selling is undertaken in motor vehicles or carriages drawn by animal power or humans (Figure 72) and produce is peddled from home to home. Street selling has the same characteristics and limitations as ambulatory selling. As scales are unavailable, produce is generally sold per unit (Figure 73).

6.3.3 Community markets

6.3.3.1 Farmers markets

A farmers market is a form of direct marketing that is located in a community or nearby where growers sell directly to numerous customers (Figure 74). Cash sales and the possibility of selling undersize or oversize units that cannot be marketed through other marketing channels are the main benefits of this system for farmers. For consumers it

Figure 71: **Grouping together similar products such as tubers and roots is a strategy used to increase sales.**

provides the opportunity to buy fresh produce or homemade products and to interact with producers in an informal environment. A farmers market becomes successful when there is cooperation and interaction among three key groups:

1. The sponsoring, organizing or promoting group, which may be a municipality, a group of neighbours, the local chamber of commerce, a farmers organization or any other association or organized group.
2. Vendors should be authentic producers including those who grow produce in their backyards to provide a means to increase their income.
3. Buyers who support market activities. It is estimated that one vendor can be supported by 800 potential buyers, therefore, a community of 8 000 residents could sustain a farmers market with 10 vendors (Marr and Gast, 1991).

Location of the market is an important factor. Different studies indicate that it is more practical to be located in close proximity to buyers than it is to vendors. Markets are often located in the town square or any other public open space. Vendors provide their own tables, racks, covers for shelter and other facilities for selling that can be easily dismantled when trading is over. Paved drives and walkways provide certain advantages in addition to adequate parking space. A tree-shaded space protected from the weather is much more desirable for both vendors and buyers.

Figure 72: **Peddling is limited by the number of items that can be transported. Some municipalities do not allow any type of street vending.**

Sponsoring or organizing institutions should charge vendors a stall fee in addition to costs for security measures, lighting and cleaning services. They are responsible for policy-making, particularly with reference to selecting who can sell at the market, type of products to be sold, fees, hours, days and months for market operation, sanctions and other operational issues. They must also arbitrate in the event of problems and disputes. The organizing institution should promote the market and maintain the market "environment", which is precisely what attracts customers.

Fruits, vegetables, honey, eggs, firewood, flowers, plants, gardening materials and other products can be sold at farmers markets. Bakery products, jams, marmalades, milk, homemade cheeses and other products may require special permits. Sales of meat and other products may be forbidden. Only farm products are permitted for sale and reselling is not allowed. Sales of crafts should be allowed in order to attract people; however, it should be limited so that the spirit of this type of market is not lost.

The main advantages of selling at farmers markets are that only a minimum investment is required to operate and there is no need for packaging materials, large volumes or a wide variety of products. Disadvantages include low volume of unit sales, the need for customers to be served and bad weather conditions.

Figure 73: **Street vending has the same limitations as peddling. If no scales are available, products are sold by the unit.**

6.3.3.2 Regional markets

Regional markets exist in many developing countries where buyers and sellers meet to trade. From an organizational point of view they are very similar to farmers markets: a sponsoring organization is responsible for policy-making; the market operates one or more days a week; stall rental is on a daily basis, etc. The main difference is that mainly wholesale operations are carried out in regional markets, although some retailing is undertaken. This system provides many small-scale farmers with the opportunity to sell their produce at a fair price.

6.3.4 Farm stall sales

Farm outlets attract many customers. This form of direct marketing has the advantage of adding value.

Location of the farm outlet is extremely important because it must be seen from a certain distance and should be located on a relatively busy road, where the speed limit does not exceed 70-75 km/hour (Lloyd *et al.,*2001). The main access routes to cities are probably the best places for these types of markets; however, they can also be located in other areas, for example, tourist areas. Safe paved roads and the availability of adequate parking space are factors to be considered (Figure 75).

Figure 74: **The informal "environment" of farmers markets is the main attraction for customers.**

Signs should clearly direct customers to the farm outlet with instructions on how to turn safely into the market. These signs should be seen from a certain distance and well in advance (between 100 and 2 000 metres) in order to allow drivers time to reduce their speed for exiting (Figure 76). The faster the traffic, the greater the distance of the sign from the exit, and the larger the size of the letters, the fewer the number of words that should be placed on the sign. For example, to be legible from 100 metres, letters should be at least 30 cm high and 6 cm wide. Twenty-two letters of that size can be read at a speed of 45 km/h but only 10 at a speed of 90 km/h (Lloyd *et al.,*2001).

There is no standard formula for designing a farm outlet; shelters, barns or special buildings may be used. They should be clean and tidy with enough space for displaying produce. They should have a rustic and simple appearance (Figure 77) to differentiate them from other produce outlets. Preferably products for sale should be produced on the farm; however, other products purchased from wholesalers can be included. Recommendations highlighted previously on how to maximize sales are also valid here. A special type of farm sale is the "U-pick" or "pick-your-own" system (Figure 78). Consumers can harvest fruits and vegetables on their own. In such farm outlets, some produce has already been harvested and packaged and is included with some crops that the customers harvest. Containers and harvesting tools should be available as well as precise instructions regarding which areas are ready for harvesting. Produce is sold by weight, volume or units.

Figure 75: **To be successful in on-farm sales, outlets should be located on a main road with ample parking and with a neat display of the goods for sale.**

For the farmer, the main benefit of this direct marketing method is that there is no need to harvest. It also eliminates the need for sorting and packaging costs, which results in lower prices, making the produce more attractive to the consumer. The customer also has the opportunity of spending a day outdoors in contact with nature, and produce is harvested at optimum ripeness. Frequently this is a recreational event for families where the objective is to make homemade jam or marmalade. For this reason, individual sales are larger than in other direct marketing methods.

Some supervision is required because many customers do not have farm experience and may unwittingly damage plants. Moreover, the liability is higher – a higher risk of accidents can occur with harvesting tools, ladders or equipment. A good emergency system should be provided including an insurance policy. Fruit crops are more appropriate than vegetables and crops with long harvesting periods and different varieties are ideal for this system. Pesticide applications and waiting periods should be carefully planned so that there is always an area ready to be harvested.

The basic rule for maximizing farm sales is the concept "the longer they stay, the more they will spend". For this reason, additional programmes should be offered such as farm tours, wagon rides, activities and games for children, on-farm walking trails, camping, craft demonstrations, nature study, petting zoo for farm animals and fishing. Other ways

Figure 76: **To draw the attention of travellers, signs must be posted in advance for a safe exit or stop and the letter size must be legible at a distance.**

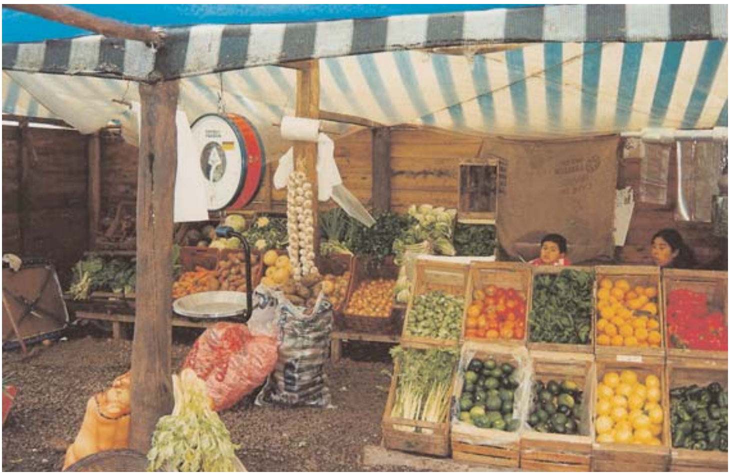

Figure 77: **A farm outlet should have a rustic and simple appearance. It should be clean, with an attractive display and adequate space for circulation.**

Figure 78: **The "u-pick" or "pick your own" system is an alternative to on-farm selling.**

of increasing income is through sales of homemade jams and marmalades, sauces, traditional or special recipes, homemade food and crafts.

6.3.5 Selling to restaurants and hotels

Direct buying by restaurants, hotels, hospitals, nursery schools and other institutions is undertaken to reduce costs and to simplify the daily supply and preparation of different dishes served. Steady year-round demand is the main advantage to the farmer. The farmer has the opportunity of adding value to the product by washing, peeling, pitting, slicing, portioning, etc. One of the main disadvantages is the difficulty of satisfying steady demand with seasonal products and prices that vary significantly. Other factors include limited storage space in restaurants and regular delivery of small volume orders, which create higher telephone and transport costs and extra documentation.

Ethnic and 'high class' restaurants belong to a special category and need to be taken into account because they often require special or premium quality produce. Contracts can be profitable provided quality produce is supplied according to specification and timely delivery. Also, a creative chef can significantly expand sales.

Appendix

Guide to good hygienic, agricultural and manufacturing practices for the primary production (cultivation-harvest), conditioning, packing, storage and transportation of fresh fruits. SENASA Resolution 510/02.

1 Objectives

1.1 Identify the essential hygienic principles for fresh fruit products in primary production (open field and greenhouses), packing, storage and transportation to achieve safe food fit for human consumption.
1.2 Give specific recommendations for general hygienic practices in the primary production (cultivation-harvest), conditioning, packing, storage and transportation of fruits.
1.3 Offer recommendations regarding good agricultural and manufacturing practices necessary to maintain the characteristics and quality of the product.
1.4 Establish work rules to preserve the safety and health of the people involved in the production chain.
1.5 Preserve the natural resources of productive areas and human health by means of the implementation of a sustainable production system.
1.6 Offer orientation for specific guides.

2 Scope

To apply this guide to manufacturing, agricultural and hygienic practices for the production of fresh fruits, from orchard planting to the delivery of fruit to the market.

3 Definitions

Agricultural water: refers to the water used in cultivation (field, orchard, etc.) for irrigation, frost control, application of phytotherapeutic agents, etc.
Agrochemical residue: Any substance or specified biological agent present in or on ONE (1) agricultural product or food for human or animal consumption as a conse-

quence of the exposure to a phytosanitary product. The term includes metabolites and impurities considered of toxicological importance.
Appropriate maturation: State of development of a product at which it can be picked.
Competent organism: The official or officially acknowledged organism to which the national state grants legal faculties to exercise certain functions.
Consumers: People who buy or receive foods with the purpose of satisfying their needs.
Contaminant: Any biological or chemical agents, foreign matter or other substances added unintentionally to food that can compromise its safety.
Contamination: The introduction or presence of ONE (1) contaminant in the food or in the food environment.
Cross-contamination: Food contamination by direct or indirect contact with the sources or vectors of possible contamination within the production process.
Danger: A qualitative expression of potential damage.
Disinfection: The reduction, by means of chemical agents or appropriate physical methods of the number of microorganisms in the building, facilities, machinery and utensils, at a level that does not allow the contamination of the food that is elaborated.
Drinking water: Water that complies with that specified in the legislation in force: Argentinean Alimentary Code, Chapter XII, Article 982.
Effluent: All liquid that is discarded after having been used in any of the operations performed.
Establishment: The environment that comprises the area and/or the building where operations and processes are performed to condition raw materials and/or ONE (1) processed food as well as storage for same.
Food: All substances or mixtures of natural or processed substances ingested by humankind that supply the organism with the materials and energy necessary for the development of the biological processes. The term “food” also includes the substances or mixtures of substances that are used in the preparation or treatment of foods, whether or not they have nutritious value.
Food innocuousness: The guarantee that food will not cause damage to the consumer when prepared and/or consumed according to its destined use.
Fresh fruits: Those that are usually sold to the consumer in their natural state or with minimum processing (natural).
Fruit handling: All the operations carried out on the fruit product to obtain a finished food at any stage of its processing, storage and transport.
Package: The container, wrapping or the packing material destined to ensure conservation and to facilitate transportation and handling of the product.
Pathogen: Microorganism able to cause damage or disease.
Phytosanitary product: Any substance, biological agent, mixture of substances or of

biological agents, destined to prevent, control or destroy any harmful organism, including unwanted species of plants, animals or microorganisms that cause damage or negative interference in the production, elaboration or storage of plants and their products.
Plague: Any species, race or biotype of plants, animals or pathogenic agents harmful to plants or plant products.
Quality: Group of aspects and characteristics of goods or services in relation to their capacity to satisfy the consumer's needs, explicit or implicit, with the observance of legal, technical and commercial requirements. *Composting*: Process that regulates organic substrata through controlled bioxidative processes, including a thermophilic initial stage, and stabilizes the organic matter, eliminating odour and reducing the pathogenic level.
Risk: Quantitative expression of the probability of occurrence of damage.
Sanity: Quality of raw materials, food products and/or propagation materials, which are free of harmful elements at the highest possible level.
Supervisor: A person who performs a sequence of observations to evaluate if the procedures conform to those established.
Traceability: The group of procedures that allows for a complete surveillance of the merchandise from the production place, lot, establishment, etc., to the destination point.

4 Primary production

4.1 Objective

To reduce the probability of crop contamination that can endanger the safety of fruit or its fitness for consumption at later stages of the food chain.

4.2 Justification

Environmental factors and management practices can produce different kinds of contamination during the cultivation of fresh fruit products.

4.3 Hygiene of the environment where raw material is produced

4.3.1 Choice of production site

- Evaluate previous history of the cultivation site and previous and current use of adjacent lots to identify possible contamination dangers.
- Do not cultivate fruit trees for fresh fruit consumption near areas with a presence of potentially harmful substances, for example:

- sewage;
- sludge;
- heavy metals;
- dangerous chemicals;
- animal faeces;
- toxic weeds;
- aerial contamination;
- places where operations with livestock or birds are made or with an unusual quantity of wild life, etc.

- These can cause the contamination of those foods or their derivatives at levels constituting a health risk.
- If the causes of contamination can be eliminated, apply a corrective plan of action before proceeding with cultivation.
- Keep records of the activities carried out on the soil, and in the event of reuse, record its productive history.

4.3.2 Soil or substrate

It is advisable that the soil or substrate be in good physical, chemical and biological condition. Drainage should be adequate to avoid the establishment of high humidity microclimates that promote the proliferation of pathogenic microorganisms.

4.3.3 Water for human consumption

- Use only drinking water.
- Evaluate the quality of the water source used by means of periodic analysis.
- If it is necessary to store water, design, build and maintain the reservoirs to prevent contamination.

4.3.4 Agricultural water (used for irrigation, washing of equipment and instruments, solutions of fertilizers and phytosanitary products, etc.)

- It should be free of human and/or animal faecal contaminants, dangerous microorganisms or substances (e.g. *Escherichia coli*, coliforms, parasites, *Shigella* sp., *Listeria monocitogenes*, heavy metals, arsenic and cyanide) and agrochemical residues.
- Evaluate the quality of the source of agricultural water by means of periodic analysis to determine microbial contamination or the presence of agrochemical residues or other harmful substances.
- Cultivation should be carried out in areas where the water used in the different productive processes does not represent, through food, a risk to the consumer's health.

4.3.5 Supply of agricultural water

Agricultural water is a resource frequently shared and therefore it is important to keep in mind the factors that affect the common hydrographic basin. Land topography as well as past and present use of the adjacent fields are factors that facilitate contamination. The presence of urban areas, industrial plants, treatment plants for waste waters, dunghills of domestic animals, landfills or high concentrations of wild fauna upstream are possible sources of contamination downstream.

4.3.6 Irrigation

Irrigation water can be an important factor in product contamination. Special care is required for water quality and for the irrigation method used, mainly close to harvest time. Although the irrigation method is chosen as a function of several factors, the contact of water with the edible part of the plant must be avoided. Drip irrigation has less contact with the product than furrow or sprinkler irrigation. The irrigation system adopted must allow for a uniform and effective distribution of water to assure the best use of the resource and to minimize negative effects on the environment.

4.3.7 Animals in the orchard

Producers should consider that:

- Livestock and other domestic animals should be kept far from the orchard during the cultivation season. The planted sectors should be wired or fenced or animals should be conveniently confined.
- Ditches, embankments, live plant fences, etc., should be constructed to separate neighbouring fields where animals are raised and to prevent runoff or drip of animal faeces because of rains, irrigation ditches or simply by superficial runoff.
- The concentration of large quantities of wild fauna should be avoided through the use of good agricultural practices to drive away or to redirect this fauna towards other areas. Visual, auditory or physical dissuasive means can be used, all in agreement with the legislation that regulates the management and protection of wild fauna.
- If working animals are used it is better not to use them during harvest.
- The working animals should be in good health, vaccinated and free from parasites and diseases.

4.3.8 Organic fertilizers

- Organic fertilizers, including those originating from organic sludge and urban organic residues, should undergo treatment (composting or other) to eliminate pathogenic agents before being incorporated in the soil. Otherwise they could contaminate the product or the surrounding environment.

- Apply the organic fertilizer well in advance of harvest to avoid any possibility of product contamination.
- According to the norms in force, it is forbidden to use sewage mud and organic urban residues that have not been previously composted as soil amendments. It must be taken into account that the restriction for the use of these organic amendments determines that they should not be applied during the cultivation period.
- Heavy metals content of organic fertilizers should be within the maximum limits established.
- Do not use organic fertilizers contaminated with heavy metals or with other chemicals for which maximum limits are not certain.
- The areas where the composting is carried out should be isolated from the cultivation sites or where the material harvested is handled or stored.
- In the case of using inorganic or chemical fertilizers, these should be registered in SENASA and used in the recommended doses, observing the established waiting periods in order to avoid leaving residues potentially toxic for human health.

4.3.9 Phytosanitary products

- Use phytosanitary products only when other control methods are not effective.
- Use only those products registered by SENASA and recommended for the specific crop/pest/disease, keeping in mind the particularities of each region.
- Verify the integrity of containers, labels and tags of the purchased products.
- Keep the phytosanitary products in their original containers with respective labels and tags.
- To avoid the possibility of contamination store these products in locked deposits isolated from cultivation sites or where the harvested product is handled or stored. These places should be well ventilated and illuminated with natural and artificial light.
- Allow access to the deposit only to properly qualified personnel who have full knowledge of handling these products and of the implicit dangers, including the possibility of contamination of the product.
- Place phytosanitary products on shelves according to their type (insecticides, herbicides, fungicides, etc.), formulation and container.
- Where phytosanitary products are stored, there must be ONE (1) list with addresses and telephones for emergencies in a visible place.
- Prepare and apply the agrochemicals observing the label recommendations concerning doses, moment of application, environmental conditions, quality of the water for dilutions, etc.
- No smoking, eating or drinking is allowed during the preparation and application of the agrochemical.

- Workers should be fully familiarized with the dangers that chemicals represent to human health, including the possibility of leaving toxic residues in the product.
- Personnel handling agrochemicals should wear appropriate clothes and should be aware of all the norms and procedures for the safe use of pesticides.
- Maintain sprayers in good condition and calibrate them properly before use.
- Wash the sprayer carefully after each application to eliminate residues and to avoid the corrosion of equipment.
- Observe the waiting periods between application and harvest.
- Containers of liquid agrochemicals should be washed three times before being perforated or destroyed.
- Elimination of agrochemical containers should have the smallest possible impact on the environment. Use the official services for collection and disposal.
- Observe the manufacturer's instructions for the destruction of containers. Do not keep or reuse them.
- Avoid exposure of humans or animals to the discarded containers.

4.3.10 Planting material

- Planting material, grafts as well as their rootstocks, should be properly identified and free from pests and diseases that may be introduced to the soil or substrate, according to Law No. 20.247 and its regulations in force.
- If available, it is advisable to use material certified by the competent official organism.
- When possible use varieties/cultivars with genetic resistance to the most important pests and diseases and which are adapted to the agroclimatic conditions of the area, as a way to minimize the use of phytosanitary products.
- Take the necessary precautions to reduce the deterioration of planting material (drying, contamination with harmful substances, pathogenic microorganisms, pests and diseases, loss of the germinating capacity, etc.) if not planted immediately.

4.3.11 Facilities

- Each establishment should be evaluated individually to identify the specific hygienic requirements. Although in most farms the permanent facilities (houses, bathrooms, sheds, tanks, mills, pumps, greenhouses, deposits, etc.) are already installed, it is important to study the general layout to avoid cross-contamination and to be able to define areas according to their higher or lower degree of contamination. It is also important to determine the flow of the produce going always from the more contaminated areas to the less contaminated ones. In the same way, within the facilities (sheds, houses, greenhouses, etc.) the flow of the produce should minimize the possi-

bility of cross-contamination. If the farm layout can be planned from the beginning, the Good Agricultural Practices concept should be kept in mind.
- The facilities and their expansions and/or improvements (windbreaks, mills, tanks, sheds, greenhouses, etc.) should have the following characteristics:

Be located in places where there is no threat to the innocuousness or aptitude of the food (contaminated environment, close industrial activities, flood possibility or infestation by plagues, areas without efficient waste disposal, etc.).
Be of solid construction and designed in such a way as to avoid the harbouring of pests and their proliferation.
Allow for adequate maintenance, cleaning, and disinfecting when it is needed.

- Enough space is needed to carry out in a satisfactory way all the operations.
- When the facilities are used for several purposes, such as a shelter for farm equipment or as a deposit for containers, animal food or seeds, it is fundamental to separate the operations susceptible to food contamination by means of compartments, reserved places or in other effective ways.
- If housing for permanent and/or temporary personnel is within the farm boundaries, it must be solidly constructed, well maintained and hygienic, with enough room for everyone.
- Electrical circuits in every facility (housing, sheds, offices, deposits, etc.) should be safe and protected with safety devices, such as differential circuit breakers, ground connection, thermal switches and double insulated cables, to avoid accidents either by direct or indirect contact.

4.3.11.1 Bathrooms and latrines

This subject is specially addressed because of the importance these facilities have in that they are possible contamination sources and their management in agriculture is difficult. It is necessary to emphasize the importance of their existence in order to avoid having field personnel urinating and defecating in the open, facilitating the contamination of fruit products under cultivation.
Incorrect management of wastewater and solid waste can cause food contamination.
- Field personnel should be provided with bathrooms, toilets, latrines and lavatories. These facilities can be permanent or portable.
- The number of bathrooms and lavatories should conform to established municipal regulations, according to the number of workers that use them.
- The easier the access to these facilities, the greater the possibilities to use them.
- The use of these facilities must be allowed at any moment and not only during the rest periods to avoid evacuations at any place (included cultivation lands).

- These facilities should not be located near sources of agricultural water or in places easily flooded or where the runoff can destroy them and contaminate the areas downstream.
- Permanent or portable toilets or latrines should be well built, with materials and fittings that are easy to clean.
- Wastes can be eliminated by tank trucks, providing there is easy access to the bathrooms through ducts that go to septic tanks located far from agricultural areas, packing sheds or other places where food is handled, or through any other system that maintains the hygiene of the working place.
- An emergency plan should exist in case of any leakage or overflow of the sewage system and personnel should be trained for this emergency.
- Bathrooms should have the necessary items for personal hygiene (toilet paper, soap, paper towels and a wastebasket).
- Bathrooms and lavatories must be cleaned and disinfected daily or with a periodicity in accordance with the intensity of their use.
- Tanks that supply water should be emptied, cleaned, disinfected and filled again with drinking water regularly.

4.3.12 Equipment, containers and instruments

- The equipment (machinery, irrigation equipment), instruments (shears, knives, clasp knives, tools, etc.) and the reusable containers (harvest containers, etc.) that come in contact with food should be designed and manufactured in such a way to ensure that they can be kept clean and disinfected to avoid food contamination.
- Materials used for their construction should not have toxicants that could contaminate food with their use.
- The equipment and instruments should function according to their specific use (sharp knives and shears, clean farm machinery in good repair, irrigation equipment in good operating condition, etc.).
- Preventive maintenance is necessary for pumps, motors, and equipment used for irrigation. Verify that pump and electric motors are ground connected to prevent electric shocks.
- Ladders used for harvest should comply with the conditions that guarantee the operator's safety.
- In the particular case of ladders with THREE (3) legs, they should be preserved with colourless materials to facilitate the view of their conservation state.

4.4 Tillage

Tilling should be carried out only to improve soil conditions and/or when the crop requires it and with techniques and equipment that minimize its impact.
Soil disinfection and/or sterilization by chemical means should be justified, giving priority to alternative practices such as solarization, crop rotations or the use of resistant cultivars.

4.5 Frost control

Frost control should be carried out according to critical temperatures and periods for each species and cultivar. If heating systems are used, those that generate the lowest emission of harmful substances and offer the greatest possible operating safety should be adopted. Heaters should have a chimney and fuels with the lowest fume emission levels should be used. Observe the legislation in force.
If overhead irrigation is used for frost control, special care should be taken with water quality to avoid the microbiological or chemical contamination of products.

4.6 Personnel

People working in primary production should maintain adequate personal hygiene, behave in an appropriate manner and know the functions and responsibilities required to protect food from contamination and deterioration. In general, they should comply with that established in item 4.7.4.

4.7 Harvest

4.7.1 Objective
Gather the produce in such a way as to keep its quality and sanitary conditions and to avoid its contamination during harvest.

4.7.2 Justification
Fruits are susceptible to damages, bruises and contamination during harvest and transport to the packing place.

4.7.3 General considerations
It is advisable to plan for activities and the required inputs for harvest and to organize personnel to work efficiently and without delays.

During the harvest:
- Keep the harvest place organized for hygiene, efficiency and the dispatch of all activities.
- Harvest when the appropriate state of maturity is reached for each product and use the best detaching method for the species (pull, cut, twist, etc.). Take a sample of the harvested product with the desirable maturity degree, size, and colour and use it as reference for the field supervisors or harvesting team leaders. Give clear instructions before starting the work, checking that the workers have understood them.
- Avoid working during hours when temperature is high, when dew is still on crop, after a rain or when environmental humidity is high.
- Under no circumstances leave harvest residues, fallen fruits and culls in the field because these will rot and contaminate the area increasing the inoculum level. This plant material must be collected and destroyed appropriately (burnt, buried, etc.).

Harvested produce must be:

- Placed carefully in the harvest or definitive container and should not be thrown, hit, pressed or rubbed.
- Transported quickly to the packing place.
- Hauled in such a way as to avoid bruising and damage. Internal farm roads should be levelled and kept clean; drivers should aware of the importance of driving carefully and at low speed; and tire pressure should be reduced.
- Load and unload containers with special care, instructing and controlling the harvesters and other workers who handle produce regarding the importance of handling.
- If produce is not packed immediately, maintain it in the shade, under an open shed or adequately covered from weather.
- Prevent dehydration, particularly during the hottest part of the day by placing shading nets, using water sprays, covering the produce with wet sackcloth and reducing the time between harvest and transport to the shed.

4.7.4 Personnel
- All personnel should have the sanitary document issued by the corresponding authority.
- All workers should take care of their own personal hygiene.
- Workers with symptoms of illness, jaundice, diarrhoea, cough, notorious skin lesions, etc., should inform the supervisor. He/she will be separated from the area where there is direct contact with food and a physician should intervene to check his/her aptitude for returning to the workplace. Any wound on the hands should be covered with adhesive bands and gloves should be used if needed.

- Jewellery and other personal objects that can harm the produce and the worker himself should be forbidden, fingernails must be short and gloves must be used if needed.
- Workers should not be allowed to carry pets to the working place. They can contaminate the produce with faeces, urine and other contaminant elements through paws, hair, etc.
- Workers should not eat in the orchard nor leave residues that can rot and produce contamination.
- Provide comfortable working conditions for workers as well as safe equipment and adequate tools with instructions regarding handling and maintenance.

4.7.5 Containers

- Wooden boxes, baskets, bins, definitive containers or any other harvest container should be made of materials suitable for food and easy to clean and disinfect. Their design should be appropriate to the work and the weight of the produce to be contained.
- Clean and disinfect the containers at the beginning of the season and every time that they are used.
- Place plastic covers or padded coverings inside the bins or harvest boxes to avoid or cushion the pressure of the produce against the walls.
- Do not overfill the containers to avoid the deterioration of the product.
- When loading the containers in the field, it is advisable to keep them covered to protect them from sun.

4.7.6 Equipment and instruments

- Keep in good repair working instruments such as shears, knives, pliers or other tools so that they will not damage the produce and will be safe for the workers.
- The equipment, tools, instruments, and harvest containers used should be cleaned and disinfected regularly during work.

4.7.7 Direct marketing of fruit products and "U-pick" systems

Many fruit establishments sell their products directly "on the plant" or allow the customers to gather the fruits by themselves through the "U-pick" system. In both cases the producer should inform the customers that the establishment has a programme of good agricultural practices, and encourage them to comply with that established in accordance with these measures.

5 Packinghouse or packing shed

5.1 Objective

Market preparation (cleaning, disinfection, selection, etc.), presentation and packing of the product should be carried out to maintain product quality, avoiding any contamination during this process.

5.2 Justification

Fruits are susceptible to damage and chemical, physical and biological contamination during conditioning and packing.

5.3 Location

Packinghouses, open sheds or any other place used for the preparation and packing of fruits should be located in areas that:

- Are free of environmental contamination caused by industrial activities or of another nature that is dangerous to the hygiene of the product and to the health of the consumer
- Are not in danger of flood risk.
- Are not exposed to any pest infestation (rodents or other animals that transmit diseases).
- Allow for the proper disposal of the water used for cleaning and treatment of produce, buildings, facilities and equipment.
- Have access roads that are paved, consolidated and compacted to allow for the passage of vehicles without contaminating the atmosphere with dust from the road and with adequate rainwater drainage. In addition, they should be conveniently separated from areas dedicated to animal raising or areas with abundant wild animals.

5.4 Size, design and layout

- Size should be adequate for the volume of produce to be processed, size of the equipment, storage capacity and with enough space for workers to move around and work comfortably.
- Design and layout of different sectors should facilitate the sanitation operations, avoiding cross-contamination from dirty areas, either by air or by contact.

- Separation of the different sectors should be carried out with specific hygienic procedures for the end pursued.
- Specific places for the storage of packing materials and chemical products used during preparation (detergents, fungicides, additives, etc.) should be provided.
- If products are packed under open sheds, they should be protected from dust with canvas or other material (as curtains), fastened at the top and at the bottom of the structure.
- It is advisable to have adequate facilities to keep tools, inputs, equipment and other materials as well as to perform maintenance work.
- There must be parking areas within the perimeter for all vehicles used in the operation and external parking space for those vehicles not related to the activity. Maximum speed limit and other traffic signals should be posted and clearly visible.

5.5 Construction

- The roof, floor, walls, doors and windows should be built with waterproof, nonporous, non-toxic materials that can be easily cleaned and disinfected.
- The floor should be of a non-slippery material resistant to traffic, with an appropriate slope to facilitate drainage and without cracks where dirt can accumulate.
- Windows should be insect proof and removable for cleaning and to avoid dirt accumulation.
- The aerial structures, roofs, stairways and elevators should be designed, built and maintained to prevent contamination and be safe for workers.

5.6 Ventilation

- Provide correct ventilation to reduce to a minimum the risk of product contamination from drops of water condensation and harmful dust or moulds, and to regulate the temperature of the environment.
- Have enough ventilation openings to allow for the periodic replacement of filters.
- Airflow should never go from a dirty area to a clean one.

5.7 Illumination

- There must be enough illumination, natural and/or artificial, to facilitate the performance of operations according to their characteristics.
- Lights should not alter the natural colour of the products.

- Light fixtures should be covered to prevent glass from shattering on produce in the event of breakage.
- The electric installation should have the necessary safety devices (differential circuit breaker, ground connection, thermal switches and double isolated wiring) to avoid accidents by direct or indirect contact.

5.8 Water

- There must be adequate facilities to distribute drinking water.
- Non-drinking water (fire control system, refrigeration, etc.) should circulate through separate pipes perfectly differentiated from those of drinking water.
- No cross connections should exist in the provision of drinking and non-drinking water.
- Drainage or similar sources of possible contamination should be designed to prevent reflux.
- If water storage is necessary, tanks should be designed, built and maintained to prevent contamination.

5.9 Equipment

- It is advisable to use equipment designed for the work and the product to be packed in order to minimize damages to the product (i.e. eliminate all type of sharp edges and avoid abrupt drops).
- Equipment, tools and machines used for maintenance work should have the safety devices recommended by the manufacturer.
- All equipment and instruments that come in contact with the produce should be made with materials that do not transmit toxic substances, odours or flavours; they should be non-absorbent and able to resist corrosion and repeated operations of cleaning and disinfection.
- Equipment and utensils used for wastes and cleaning should be marked accordingly indicating their use and they should not be used for edible products.

5.10 Facilities for the hygiene of personnel

- There must be facilities suitable for personal hygiene.
- The sanitary facilities and wardrobes should not have direct access or communication with the areas where produce is handled.
- It is advisable that the access doors to the sanitary facilities close automatically.
- Cleaning and disinfection of the sanitary facilities should be carried out daily, with a periodicity in accordance with the intensity of their use.

- There must be enough drinking water (cold-hot) for the adequate hygiene of the workers, with automatic faucets to avoid manual operation and accessories for hygienic hand washing and drying (soap and disposable towels).
- Place posters with the hygienic norms that the workers must observe in all the necessary places.
- When packing is done under more modest conditions or directly in the field, there must be specific places for toilets and drinking water supplied by tanks or cisterns for the workers (see item 4.3.11.1).
- It is advisable to designate a suitable place for the wardrobe and dressing room, physically separated from the sanitary facilities and from the areas where food is handled.

5.11 Maintenance, cleaning and safety of the facilities and equipment

- Order should be maintained and appropriate cleaning and disinfection of the area, facilities, equipment and utensils should be carried out minimally on a daily basis.
- The volume, temperature and pressure of water should be adequate for the operations as well as for cleaning.
- The equipment should be checked to see that it is in good working order.
- The facilities should be disinfected frequently with permitted products.
- Pest infestations should be controlled immediately. Any treatment with chemical, physical or biological products should be carried out without threatening food safety.
- Access roads and external sectors of the facilities should be kept clean, clear and free of residues, weeds or spontaneous vegetation that may harbour pests or rodents.
- Wastes produced during preparation for the market should be removed from the facilities and disposed in such a way to avoid the contamination of food, drinking water, packing materials, equipment, etc.
- There must be adequate provisions for the prevention and control of fires according to the size of the facilities as well as first aid kits. Their condition should be verified periodically.

5.12 Processes

- The quality, hygiene and innocuousness of the product should be preserved after harvest whether it was prepared in a packinghouse, open shed or in the field.
- Other treatments are product specific, for example, cleaning, disinfection, protection, enhancement, selection and packing.

5.12.1 Reception of the product

- Products coming from the field should not be accepted if they contain parasites, undesirable microorganisms, agricultural chemicals or other toxic substances that cannot be reduced to an acceptable level with postharvest treatments. When appropriate, laboratory analysis should be carried out to check if these raw materials are fit for consumption.
- Verify the quality and general condition of the product. For some products it is necessary to determine the maturity degree in order to assign the most suitable destination.
- Raw materials should be stored under conditions that guarantee protection against contamination and reduce to a minimum damage and deterioration
- Raw materials that are inadequate for fresh consumption should be removed and disposed of in such a way to avoid the contamination of food, water and the environment.

5.12.2 Conditioning

Dirt should be eliminated (soil or other foreign materials), in a wet (with water) or dry way (vibration, brushing, etc.), according to the product.
When the wet method is used it must be considered that:

The cleaning water should be drinking water containing ONE (1) sanitizer. The most commonly used is sodium hypochlorite, at a concentration lethal to pathogens on the surface of product but without damaging it.
Periodic water renovation is necessary to avoid excessive accumulation of dirt and fungus spores.
Effectiveness of the disinfection treatment is a function of the concentration of the active principle and the time of the treatment. The pH and the accumulation of organic matter alter the concentration of this active principle and therefore it is fundamental to monitor the pH and replace the solution periodically.
If hydrocooling is performed, drinking water containing the sanitizer should be used. It must kept in mind that if water is recycled, it should be changed regularly to prevent accumulation of dirt with the successive passages.
Permitted detergent substances should be used for washing and must then be rinsed off to avoid leaving residues.

- If the product is dried by hot air, temperature and treatment time should be strictly controlled.
- For waxing and/or postharvest disease control with fungicides:

- Use only substances approved by SENASA.
- If simultaneously applied, control the proper operation of the mixing mechanism in the container where wax and fungicide are mixed.
- Control the application equipment for wax and/or fungicides because nozzles can be obstructed, drip or produce an uneven coverage of product.
- An inadequate fungicide or wax application can affect consumer's health.

5.12.3 Packing

- Only new and clean materials should be used. When using wooden containers observe the current legislation.
- Reusable containers should be cleaned and disinfected correctly and must be approved by SENASA.
- If packing materials are stored, the area must be closed and adequately protected against the entrance of pests and rodents.
- Assign responsibility for checking, removing and destroying containers in bad condition and/or dirty.
- Packaged produce, ready to be delivered to the market or to be stored, should not cross over the dirty area or areas corresponding to previous preparation steps to avoid cross-contamination.

5.13 Personnel

- Personnel should have the necessary sanitary documents issued by the corresponding authority.
- They should be qualified for the tasks they perform.
- They should maintain their own personal hygiene, that of their clothes and equipment for which they are responsible.
- No smoking, eating, drinking, spitting or chewing gum is allowed in the working place.
- Clothing should be suitable for the type of work he/she performs.
- Hands should be washed conscientiously every time workers use the bathroom, before starting to work or after handling contaminated materials.
- Short and well-maintained fingernails should be required and, if necessary, the use of gloves. Cosmetics are not allowed on hands because they can stain or contaminate produce with odours and/or flavours.
- Wounds on the hands must be covered correctly with adhesive bands.
- A person with symptoms of illness, diarrhoea, cough, notorious skin lesions, etc., should report his/her condition to the supervisor, leave the area where there is direct

contact with food and be seen by a physician. Before returning to work, his/her health condition should be checked.
- Breaks should not be taken in the working place.
- Short working shifts are recommended to reduce fatigue caused by routine work.
- Visitors, inspectors, buyers and other non-working people must observe the hygienic practices established when they handle or inspect the product.

6 Storage

6.1 Objective

Maintain the quality, hygiene and innocuousness of the harvested product.

6.2 Justification

A correct storage of the product prolongs its shelf life.

6.3 General considerations

- Keep in mind the storage environmental conditions (temperature, humidity and atmosphere) required for each product.
- If several products are stored in the same place, their ideal storage conditions should be similar.
- Storage facilities should be designed and built to:

Allow adequate maintenance and cleaning.
Avoid the access and nesting of pests.
Allow efficient protection of food from contamination.
Reduce fruit deterioration to a minimum (i.e. by controlling temperature and humidity).
- Food should not be stored in the same place with products that affect its conservation time or organoleptic characteristics, for example, fish, fertilizers, gasoline and lubricant oils.
- Storage facilities should be kept clean and correctly disinfected.
- Forklifts used to handle produce should not be used to move garbage, waste, equipment, etc. If so, wash and disinfect properly.

7 Transportation

7.1 Objectives

Help to retain innocuousness and integrity of harvested products.

7.2 Justification

There is a great possibility of contamination during the transportation and handling of produce.

7.3 General considerations

- Products should be protected from environmental conditions and, when necessary, refrigerated during transportation to avoid contamination or deterioration.
- Transportation vehicles should be completely clean, disinfected and dry before loading.
- It is advisable to load and unload during daytime (at night, artificial light attracts insects that can get into the containers) in places separated from the area where the product is processed, but protected from weather conditions and from possible contamination.
- Load and unload pallets or individual containers gently to avoid wounds and bruises caused by impact or vibration.
- Secure the load to the compartment to avoid movement during travel that could harm the quality of the product and to avoid possible harm to workers.
- Keep in mind the compatibility of ideal holding conditions for each product in mixed loads (temperature, ethylene production and sensitivity to it, humidity, etc.).
- Non-food products can contaminate fruits with foreign odours or toxic residues or any other substance that implies a health risk.
- For refrigerated transport the following suggestions are made:

The loading area must be refrigerated.
Pre-cool the vehicle compartment to the desired temperature before loading it.
Place the pallets or individual containers inside the vehicle in such a way to ensure cold air circulation through and around them.
Check the correct operating condition of the refrigeration equipment and make sure that it is adapted to the requirements of the product in particular.
Include thermographs in the load to check that the right temperature is maintained during transportation.

Confirm the integrity of walls, floor, roof and doors of the load compartment because heat, dirt and insects can enter through any opening or crack, or cold and humidity can be lost. Check the correct operation and closing of ventilation doors and openings.
Verify that the equipment is clean because remaining odours from previous loads, residues of toxic substances and the presence of insects or their nests may affect the quality of the load. In the same way, dirt or product residue could affect air circulation.

- Park the transportation vehicles in places isolated from the area where products are handled to avoid contamination by combustion gases.

- Vehicles should have the safety devices established by the legislation in force (National Law of Transport).
- Drivers should have the corresponding authorization for driving transportation vehicles.

8 Training

8.1 Objective

To ensure that personnel working at each step in the cultivation and preparation for market have full knowledge of good hygienic and agricultural practices and are aware of their role and responsibility in maintaining the hygiene, quality and innocuousness of the products.

8.2 Justification

Training is of fundamental importance in any system of food hygiene. Insufficient training and/or instruction and supervision pertaining to the hygiene of any person that participates in food handling, represents a possible threat to the safety of food products and to their fitness for consumption.

8.3 Knowledge and responsibilities

- There must be supervisors at each step in the cultivation and preparation for market who should control the production and handling procedures as well as the products harvested.

- Workers should have deep knowledge of their tasks at any of the production steps to obtain the fresh fruit product (production/conditioning/packing/storage/transportation), and should also be responsible for its protection from contamination and deterioration.

8.4 Training programme and knowledge update

- Train and supervise the personnel periodically in order to detect and correct mistakes.
- Implement periodic training and updating sessions.
- Training should be designed to allow for a better understanding of the importance of certain handling practices, in particular regarding sanitation or personal hygiene.
- It is advisable to have joint training programmes for personnel who work at different steps of the production process.
- Training programmes should be revised periodically and, if necessary, they must be updated according to the demands of the process.
- All workers that handle and use agrochemicals, and those working with dangerous or complex equipment, should receive specific instruction and training and must be qualified for that job.

8.5 Supervision

Trained personnel should be supervised periodically. Supervisors should have the necessary knowledge on principles and practices of food hygiene in order to evaluate possible risks and to adopt the necessary measures to solve the problems they face.

9 Documentation and records

9.1 Objectives

- To detect in time and at what stage of the process there is an error and to solve it appropriately.
- Establish the exact origin of the production.
- Know the production procedures of the product.
- Reduce error risks inherent to purely oral communication.

9.2 Justification

Documentation favours quick tracking of problematic situations.

9.3 General considerations

- Document all the tasks that constitute the different processes. Create instructive documents (specifications and handling of equipment, procedures to apply chemical products, etc.) and record data (monitoring of the concentration of the microbiological and chemical level in the water, etc.). The minimum information that should be known includes: information about the producer and production parameters, information on workers, ways of production, equipment and techniques, raw material, inputs and ingredients, weather conditions, phytosanitary treatments, storage, transportation, analysis results, incidents, modifications, etc.
- Ensure that all workers are well instructed regarding the knowledge needed for any stage of the production process.
- It is useful to provide information on each product lot of primary production (cultivation-harvest), packing procedures, storage conditions and transportation.
- The instructive documents should be written following a logical sequence of the procedures or tasks in an imperative, precise, clear language, accessible to the readers. They should be kept up to date.
- Forms for recording data should be easy to complete and should have enough space for the information.
- Record information on incoming products such as quantity, general condition of the product, maturity indexes, etc.
- Plans, procedures and flow charts should be available where necessary.
- According to the production areas and species produced, required information must be collected.

10 Traceability and product recall

- All people responsible for the production-marketing chain must design a set of procedures to ensure the surveillance and characterization of the product from any point in the food chain. This implies the existence of a documentation and recording system that allows for the retroactive tracking of the product throughout the whole chain.
- To implement a traceability scheme it is necessary to have documents that accompany the product containing all the information from origin.

- With a traceability system, if there is a claim from a client or if some danger to the safety of the consumer is detected, the packers will be able to locate and recall the product totally and quickly and investigate the origin of the problem.
- Products that could represent a danger should be kept under surveillance until they can be eliminated appropriately.

Glossary

Common names for fruits and vegetables in Latin America and the Caribbean.

PRODUCT	**SCIENTIFIC NAME**	**COMMOM NAMES IN LATIN AMERICA AND CARIBBEAN**
Amaranth	*Amaranthus spp.*	Biedo, amaranto, espinaca china
Apple	*Malus pumila*	Manzana
Apricot	*Prunus armeniaca*	Damasco, albaricoque
Asian pear	*Pyrus pirifola*	Pera asiática
Asparagus	*Asparagus officinalis*	Espárrago
Atemoya	*Anona squamosa x A. cherimola*	Atemoya
Avocado	*Persea americana*	Palta, aguacate, avocado
Babaco	*Carica pentagona*	Babaco
Banana	*Musa paradisiaca*	Banana, plátano, cambur
Barbados cherry	*Malpighia glabra*	Acerola, cereza de Barbados, cereza de las Antillas
Basil	*Ocimum basilicum*	Albahaca
Beans	*Phaseolus vulgaris*	Poroto seco, ejote, frijol
Beet	*Beta vulgaris*	Remolacha, betabel
Belgian endive	*Cichorium intybus*	Endivia, endivia belga, witloof
Bell pepper	*Capsicum annum*	Pimiento, chile, morrón, pimentón, ají

PRODUCT	SCIENTIFIC NAME	COMMOM NAMES IN LATIN AMERICA AND CARIBBEAN
Black sapote	*Diospyros ebenaster*	Sapote negro
Blackberries	*Rubus spp.*	Mora, zarzamora
Blueberries	*Vaccinium sp.*	Arándano azul
Bok choy	*Brassica chinensis*	Bok Choy
Breadfruit	*Artocarpus alths*	Fruto árbol dei pan
Broad beans	*Vicía faba*	Haba
Broccoli	*Brassica oleracea var. italica*	Brocoli, brecol
Brussels sprouts	*Brassica oleracea var. gemmifera*	Repollo de Bruselas, coi de Bruselas, repollitos
Cabbage	*Brassica oleracea var. capitata*	Repollo, coi
Cactus leaves	*Opuntia spp.*	Nopales, nopalitos
Caimito	*Chrysophy11um cainito*	Caimito, sapote caimito
Calamondin	*Citrus microcarpa*	Calamondin, lima de las Filipinas
Canistel	*Pouteria campechianá*	Sapote amadilo
Carambola, starfruit	*Averrhoa carambola*	Carambola, fruta estrella
carrot	*Daucus carota*	Zanahoria
Cashew apple	*Anacardium occidentale*	MaraM6n, anacardo
Cassava	*Manihot esculenta*	Yuca, mandioca, guacamote, cazabe
Cauliflower	*Brassica oleracea var. botrytis*	Coliflor
Celeriac	*Apium graveolens var. rapaceum*	Apionabo, apio de raíz
Celery	*Apium graveolens var. dulce*	Apio
Chayote	*Sechium edule*	Alcayota, chayote, gúisguil
Cherimoya	*Annona cherimola*	Cherimoya, chirimoya, anona, anón
Chicory	*Cichorium intybus*	Achicoria

PRODUCT	SCIENTIFIC NAME	COMMOM NAMES IN LATIN AMERICA AND CARIBBEAN
Chinese cabbage	*Brassìca campestris*	Repollo chino, coi china
Chives	*Allium schoenoprasum*	Cebollino, ciboulette
Coconut	*Cocos nucifera*	Coco
Cranberries	*Vaccinium sp.*	Arándano rojo
Cucumber	*Cucumis sativus*	Pepino, pepinillo
Currants	*Ribes spp.*	Grosella
Custard apple	*Annona spp.*	Anona, anón, corazón de buey
Dates	*Phoenix dactyfera*	Dátiles
Durian	*Durio zibethinus*	Dudón,durio
Eggplant	*Solanun melongena*	Bereniena
Escarole	*Cichorium endivia*	Escarola, escarola hzada
Feijoa	*Feijoa sellowiana*	Feijoa
Fennel	*Foeniculum vulgare*	Hinojo
Figs	*Ficus carica*	Higos
Gadic	*Allium sativum*	Ajo
Ginger	*Zíngiber officinale*	Jenjibre
Globe artichoke	*Cynara scolymus*	Alcaucil, alcachofa
Grape	*Vitis vinifera*	Uva
Grapefruit	*Citrus paradisi*	Pomelo
Green onions	*Allium cepa*	Cebolla de verdeo
Guava	*Psidium guajava*	Guayaba
Horseradish	*Armoracia rusticana*	Rábano picante, rábano de caballo
Husk tomato	*Physalis peruviana*	Tomatillo, uchuva, tomate verde, miltomate

PRODUCT	SCIENTIFIC NAME	COMMOM NAMES IN LATIN AMERICA AND CARIBBEAN
Jaboticaba	*Myciaria caulifior*	Jaboticaba
Jackfruit	*Arlocarpus heterophyllus*	Jaca
Jerusalem artichoke	*Helianthus tuberosus*	Topinanbur, cotufa, alcachofa de Jerusalem
Jicama	*Pachyrhizus tuberosum*	Jicama
Kale, collards	*Brassíca oleracea var. acephala*	Coi dzada Coi crespa
Kiwano	*Cucumis africanus*	Kiwano
Kiwifruit	*Actinidia chinensis*	Kiwi, grosella china, uva espina
Kohlrabi	*Brassica oteracea var. gongyloes*	Colinabo, colrábano
Kumquat	*Fortunella japonica*	Kumquat, naranjita china, naranjo enano
Leek	*Allium ampeloprasum*	Puerro
Lemon	*Citrus limon*	Limón, limón real
Lettuce	*Lactuca sativa*	Lechuga
Limabean	*Phaseolus lunatus*	Poroto Lima, ejote lima, haba lima, frijol lima
Lime	*Citrus aurantifolia*	Lima, lima ácida, limón
Longan	*Euphorbia longana*	Longan
Loquat	*Eriobotrya japonica*	Níspero de Japón
Lychee	*Litchi chinensis*	Litchi
Malanga	*Xanthosoma spp.*	Maianga, cocoyam
Mamey	*Calocarpum spp.*	Mamey, sapote Mamey
Mandarin	*Citrus reticulata*	Mandarina
Mango	*Mangifera indica*	Mango
Mangosteen	*Garcinia mangostana*	Mangostán
Melon	*Cucumis melo*	Melón

PRODUCT	SCIENTIFIC NAME	COMMOM NAMES IN LATIN AMERICA AND CARIBBEAN
Nectarine	*Prunus persica*	Nectarines, nectaflna, pelones, melocotón
Okra	*Abelmoschus esculentus*	Okra, ocra, Quimbombo, chaucha egipcia, molondrón, gombo
Olives, fresh	*Olea europea*	Aceituna fresca, olivas
Onions	*Allium cepa*	Cebolla bulbo
Orange	*Citrus sinensis*	Naranja
Oriental radish	*Raphanus sativus*	Daikon, rábano chino, rábano negro
Papaya	*Carica papaya*	Papaya
Parsley	*Petroselinum crispum*	Perejil
Parsnip	*Pastinaca sativa*	Chirivia, pastinaca
Passionfruit	*Passiflora edulis*	Maracuyá
Peach	*Prunus persica*	Durazno, melocotón
Pear	*Pyrus communis*	Pera
Peas	*Pisum sativum*	Arveja, chícharo, guisante, arveja dulce
Pepino	*Solanun muticatum*	Pepino dulce
Persimmon	*Diospyros kaki*	Kaki, caqui, sapote japonés
Pineapple	*Ananas comosus*	Ananá, piña
Pitaya	*Acanthocereus pitahaya*	Pitaya
Plantain	*Musa paradisiaca*	Banano verde, piátano macho, banana de freir
Plums	*Prunus domestica*	Ciruelas
Pomegranate	*Punica granatum*	Granada
Potato	*Solanun tuberosum*	Papa, papa inglesa, patata, turma
Prickly pear	*Opuntia spp.*	Tuna
Pumpkin	*Cucurbita spp.*	Zapallos, calabaza, güicoy, ayote, pipián, auyama

PRODUCT	SCIENTIFIC NAME	COMMOM NAMES IN LATIN AMERICA AND CARIBBEAN
Quince	*Cydonia oblonga*	Membrillo
Radicchio	*Cichorium intybus*	Radichio
Radish	*Raphanus sativus*	Rabanito
Rambutan	*Nephelium lappaceum*	Rambutan
Raspberries	*Rubus idaeus*	Frambuesa
Rhubarb	*Rheum rhabarbarum*	Ruibarbo
Rutabaga	*Brassica napus var. napobrassica*	Rutabaga
Salsify	*Tragopogon porrifolius*	Salsifí
Sapodilla	*Achras sapote*	Chicosapote, níspero, chicie
Scorzonera	*Scorzonera hispanica*	Salsifí negro
Snapbean	*Phaseolus vulgaris*	Chaucha, ejote, habichuela, poroto chaucha, judía, vainita
Snow peas	*Pisum sativum*	Arveja china
Soursop, guanabana	*Anona muricata*	Guanábana, corozol
Spinach	*Spinacia oleracea*	Espinaca
Squash	*Cucurbita spp.*	Zapallito, calabacita, calabacín, zuchinis, pipián, güicoy tiemo
Strawberries	*Fragana spp.*	Frutilia, fresa, fresón
Sweet cherries	*Prunus avium*	Cereza
Sweet corn	*Zea mays*	Choclo, maiz dulce, elote
Sweet potato	*Ipomoea batatas*	Batata, camote, boniato
Swiss chard	*Beta vulgaris var. cycla*	Acelga
Tamarind	*Tamarindus indica*	Tamarindo
Taro, eddoe, dasheen	*Colocasia esculenta*	Taro
Tart cherries	*Prunus cerasus*	Guinda, cereza ácida

PRODUCT	SCIENTIFIC NAME	COMMOM NAMES IN LATIN AMERICA AND CARIBBEAN
Tomato	*Lycopersicon esculentum*	Tomate, jitomate
Tree tomato, tamarillo	*Cyphomandrea betacea*	Tomate de árbol, tamarillo
Turnip	*Brassica rapa var. rapifera*	Nabo
Watercress	*Nasturtium officinale*	Berro
Watermelon	*Citrullus lanatus*	Sandía, patilla
White sapote	*Casimiroa edulis*	Sapote bianco
Yam	*Dioscorea spp.*	Ñame

Source: Cantwell, 1999; McGregor, 1987.

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