# Training manual on postharvest handling and marketing of horticultural commodities



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# TRAINING MANUAL ON
# POSTHARVEST HANDLING AND MARKETING OF HORTICULTURAL COMMODITIES

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# FOREWARD

**The idea of compiling this training manual on the "Postharvest Handling and Marketing of Horticultural Commodities" emerged during the 1st Postharvest Training Workshop that was held in Amman, Jordan in 2003. Work on preparing this manual started after the meeting, but was stopped afterwards to be resumed again in April 2007 when the suitable means were available.**

**We do not assume that this manual is a perfect reference as it was not possible to cover all crops and topics. However, we hope that we were able to compile a Regional Base that included the most important postharvest technologies such as maturity indices, suitable harvesting timing, pre-harvest and postharvest handling of crops, fast cooling, preparation of facilities, packing, packaging, transportation and storage. This training manual included more than 29 crops (vegetables, fruits and ornamentals). A separate chapter was dedicated to the marking of crops which covered several topics; most important of which is the quality of crops, quality assurance and available outlets.**

**The authors hope that this training manual will contribute to the enrichment of the technical library from one side and to be considered as a tool for farmers, handlers, sellers and exporters to implement new methods in the production of high quality crops, methods and timing for harvesting, handling, storage, necessary handling both before and after harvesting and finally to prepare the crops for local marketing and for export.**

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# CHAPTER ONE

# POSTHARVEST TECHNOLOGIES

# CONTRIBUTION OF FRUITS AND VEGETABLES TO HUMAN NUTRITION AND HEALTH

Fruits and vegetables are very important for human nutrition and health. Diet low in fat and rich in fruits and vegetables, along with exercise and weight control can help prevent some diseases such as heart diseases and some types of cancer. Many phytochemicals found in fruits and vegetables have a remarkable ability to disrupt the formation of tumors and in the prevention of other diseases. Phytochemicals have several modes of actions, but many of them act as antioxidants.

Figure 1. Some fruits and vegetables

Some important health components in fruits and vegetables include:
**Vitamins**. Fruits and vegetables are important sources of vitamins (Table 1). Vitamins are commonly classified into water-soluble (vitamin C, thiamin, riboflavin, niacin, B6, B12, folacin, biotin and pantothenic acid) and fat-soluble (vitamin A, D, E and K). Generally water-soluble vitamins are more susceptible to postharvest losses than fat-soluble vitamins. Vitamin C (ascorbic acid) is very susceptible to breakdown. Vitamins A and B are much less susceptible to losses, but can be degraded at high temperature and in the presence of oxygen. Some of the postharvest factors that can cause losses in vitamins include: high temperature, high oxygen content and mechanical injury. Vitamins C and B are not stored in the human body and must be replenished daily. However, Vitamins A, E and D can be stored in the human body.

**Table 1.** Vitamins present in some fruits, vegetables and root crops.

| Vitamin | Source |
|---|---|
| A (retinol) | Carrots, green leaves (carotene), papaya, tomato. |
| $B_1$ (thiamin) | Green vegetables, some fruits |
| $B_2$ (riboflavin) | Green leafy vegetables, pulses |
| $B_6$ (Pyridoxin) | Bananas, peanuts |
| Niacin (nicotenic acid) | Peanuts, pulses |
| Folic acid | Broccoli, Avocado, beets, cabbage, lettuce, dark green leaves, spinach |
| C (ascorbic acid) | Cauliflower, citrus, guava, mango, papaya, spinach, sweet pepper, tomato |

**Antioxidants**. Fruits and vegetables contain many phytochemicals that have positive health effects, by acting as antioxidants. Vitamins C and E are potent antioxidants. They can inhibit the synthesis and action of free radicals. About 90% of the sources of vitamin C in the human diet are from fruits and vegetables. Several polyphenols, found in many plants, are very important for health and several of them are antioxidants.

**Pigments**. Fruits and vegetables contain several pigments that have positive health effects. Plant pigments are diverse and are classified in 4 general groups: chlorophylls, Carotenoids, Flavonoids and Betalaines. Several carotenoids have been shown to act as antioxidants, and some of them are pro-vitamin A. For example, lycopene (a carotenoid found in tomato) is linked with several positive effects including the reduction of the risk of prostate cancer. Beta-carotenes, found in many plants such as carrots, are pro-vitamin A. Several flavonoids have been associated with the reduction and/or prevention of several diseases, including some types of cancer.

**Fibers**. Many fruits and vegetables are good sources of dietary fibers, which are linked to several positive health effects, including the reduction in the risk of colon cancer, hernia, diabetes, obesity and constipation.

**Mono-unsaturated fats**. Mono-unsaturated fats are found in several fruits and vegetables as olives, peanuts, and avocado, and they are healthier than the saturated fats. They do not promote cancer, nor do they cause heart problems. Saturated fats are found mainly in animal products such as meat, cheese, lard and butter. They are notorious for promoting heart disease, but their role in cancer is not clear yet.

**Minerals**. Fruits and vegetables contain about 0.1 to 4% total minerals. These include $N_2$, P, K, Ca, Mg, Na, Cl, S, Fe, Cu, Co, Mn, Zn, I, Mo.

**Examples of the major types of cancer and relation with the diet**

Conclusions by the World Cancer Research Fund and the American Institute for Cancer Research indicate that poor eating habits account for a third of all cancer, about the same proportion attributable to smoking. Diet rich in fruits and vegetables and less fats, along with exercise and weight control, is thought to be able to reduce cancer incidence by 30-40%, equivalent to about 3-4 million cases per year worldwide. Diet and lifestyle are thought to be effective in preventing, or at least reducing the major cancer types such as breast, prostate, colon, and lung cancer. In Thailand and Sri Lanka, for example, about 2-3 of every 100,000 women die of breast cancer every year, while 30 to 40 women die in the USA, and diet might be the reason for that. Potential reduction through diet and style can reach up to 33 to 50%. Potential reduction of prostate cancer through diet and lifestyle is 10 to 20%, and risk may be reduced by eating cooked tomatoes, among other things. Potential reduction of colon/rectal cancer through diet and lifestyle is about 60 to 75%, and risk may be reduced with a diet rich in calcium and dietary fibers. Potential reduction of lung cancer through diet, lifestyle and not smoking is 90 and 95%, and risk may be reduced by consumption of vegetables such as carrots.

Several components in fruits and vegetables were shown to interfere in the different processes of developing of malignant tumor cells. These processes are as follow: initiation of potentially cancerous changes in a cell´s DNA altering the genetic make-up of the cell. The cell usually divides more freely than usual. Several causes can lead to this problem, among the most important are free radicals generated by oxygen. Active oxygen molecules (free radicals) damage structural and macromolecular components of the cell. They are also capable of generating more free radicals from other chemical components. Procarcinogens (chemical carcinogens) are other possible causes of this process. The body contains several mechanisms to eliminate the negative effects of procarcinogens. This is done through 2 sets of enzymes produced in the liver called phase 1 and phase 2 enzymes. Phase 1 enzymes break-down these chemicals into fragments enabling them to become carcinogens and capable of damaging cellular DNA. Phase 2 enzymes can bind with these fragments and eliminate them. Antioxidants such as polyphenols in green tea, lycopene in tomatoes, vitamin C and E and beta carotene in several fruits and vegetables can act against free radicals, and therefore act as protectors. Other possible protection against chemical contaminants procarcinogens are allyl sulfides in garlic and onions, which are effective in limiting the production of phase 1 enzymes. Sulforaphane found in broccoli, cauliflower, and other cruciferous promote the production of phase 2 enzymes. Estrogens seem to promote fast growth of breast cells in women, and a possible prevention measure are the isoflavones in soy products and some vegetables, which act as week estrogen and compete with estrogen.

The progression of the cancerous lesion into a mass that can invade other tissues is possibly caused by tumor cells that release growth factors promoting the development of new blood vessels, a process known as angiogenesis. Oxo-2 inhibitors such as the resveratrol in red grapes may suppress the production of growth factors by the tumor.

**Some potential health hazards of horticultural crops**

Horticultural crops can be the cause of some health hazards when they are not used in adequate sanitary manners. Some of the possible hazards may include:

**Toxins**. Some natural toxins such as alkaloids can be produced in potato exposed to light, however they can be eliminated by interrupting the exposure to the light, and storing the potato in the dark. Mycotoxins such as aflatoxins can be produced in some dried fruits and nuts infected with *Aspergillus flavus*. Aflatoxins are the most known potent carcinogens. The infection of apples by *Penecillium expansum* results in the production of another mycotoxin (patulin).

**Micro organisms**. Bacteria can be developed especially in some vegetables (due to their high pH), and therefore they can be a potential health hazard, unless they are disinfected adequately before consumption.

**Agricultural chemicals such as pesticides and heavy metals**. Horticultural crops can be a major vehicle in the contamination with different agricultural chemicals, especially pesticides. The presence of these chemicals can be due to their intentional use either before or after harvest or due to other external contamination sources such as industries and contaminated water.

**Avoidance of health hazards**

1. Control of decay organisms by avoiding mishandling/rough handling of horticultural crops,and the use of adequate postharvest technologies such as refrigeration.
2. Avoid the excessive use of pesticides, especially those that are known to cause health hazards.
3. Make sure that irrigation water (especially that coming from, or pass close to industrial plants) is not contaminated with agricultural chemicals (pesticides, heavy metals, etc).
4. Use adequate treatments that can decrease or eliminate sources of hazards. Detergents such as soaps are important to reduce or eliminate some contact pesticides from the surface of horticultural crops. Antibacterial agents such as chlorine (20-100 ppm) and iodine are very effective.

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# POSTHARVEST LOSSES

Major quantities of horticultural crops are lost after harvest, especially due to improper handling. These quantitative and qualitative losses, estimated to be as high as 50% in most of the developing countries, are very important from the stand point of human nutrition and health and national economy and ecology. Even in developed countries, like USA, postharvest losses are significant (up to 20%). These are losses in nutrition, in land used for cultivation, energy (fuel), machinery used, fertilizers, chemicals, irrigation water, labor force, etc, and above all they are significant economic losses. The increase in yield and productivity is lagging significantly behind the increase in world population, and the nutritional need in the world. Therefore, reduction in postharvest losses should be considered as a strategic requirement, especially in developing countries. The increase in yield and productivity, without reducing postharvest losses, will not be sufficient in securing the availability of food in the world.

**Causes of postharvest losses**
There are many causes for postharvest losses, including:

**Metabolic**. All fresh horticultural crops are live organs. The natural process of respiration involves the breakdown of food reserves, and the aging of these organs, and thus to food losses.

**Developmental**. These include sprouting, rooting, seed germination, which lead to deterioration in quality and in nutritional value.

**Mechanical**. Major losses in fresh horticultural crops are due to mechanical damage and rough handling. Overfilling and improper containers increase mechanical damage (Fig 1).

**Diseases**. Many decay organisms can attack horticultural crops leading to deterioration and losses (Figure 2).

**Insects**. Many insects can infest horticultural crops, especially before harvest resulting in significant losses.

**Temperature**. High temperatures and the lack of refrigeration can lead to significant quantitative and qualitative losses. Low temperatures (0-10ºC) can cause chilling injury and losses to several chilling sensitive commodities. Exposure of produce to sun enhances wilting and decay (Figure 3).

**Relative humidity**. Low relative humidity promotes water loss and shriveling, and increases qualitative and quantitative losses.

**Atmospheric composition**. The high content of $O_2$ in the atmosphere increases ethylene production and respiration. The reduction of $O_2$ and the increase in $CO_2$ concentrations in the atmospheres reduce metabolic activity and deterioration.

**Transport**. Losses during transport, especially when not refrigerated, can be very significant, due to mechanical damage, lack of use of refrigeration, use of inappropriate packages, inadequate air flow and circulation, etc.

**Marketing**. Losses are common during marketing, especially when fresh commodities are exposed to heat.

**Consumption**. Losses during consumption can be due to inadequate preservation methods at home, methods of cooking and preparation such as peeling, consumption styles, etc.

**Means for reducing postharvest losses**

- Harvest products at optimum maturity, and adequate (cool) time.
- Protect the product from exposure to the sun after harvest.
- Avoid mechanical injury during harvesting.
- Use of pre-cooling and refrigeration.
- Use of appropriate high relative humidity during storage and transport.
- Avoid infestation with diseases and insects, and use adequate control measures.
- Use appropriate packing and packaging systems.
- Transport products adequately.
- Store the product properly at the appropriate conditions.
- Adequate handling (avoid rough handling) of the produce during all the postharvet chain.

Figure 1. Rough handling, wrong marketing systems, over filling in the containers increase damage and losses (Dr. Elhadi Yahia).

Figure 2. Losses due to decay are very common (Dr. Elhadi Yahia)

Figure 3. Inadequate market infrastructure, improper marketing systems, improper containers, exposure of produce to sun, etc increase losses (Dr. Elhadi Yahia).

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# WATER LOSS

Fresh horticultural crops have high water content (75-95%). Internal relative humidity of perishables horticultural crops is considered to be 95-98% (very high water activity), and therefore their metabolic activity is very high. Therefore, water content and water losses in horticultural crops are very important for several reasons.

All fresh plant tissues loose water because of the process of transpiration. Water loss has several negative effects including weight (economic) loss, quality deterioration, losses of water soluble components such as vitamins, loss of flavor components, loss of color intensity, etc. Water loss is accelerated at high temperature and/or at low relative humidity.

Water loss can be measured by determining the weight loss (simplest method) over a period of time, which is mostly due to water loss, rather than to loss in organic materials.

**Relative Humidity (RH)**
RH is the ratio of water vapor pressure in air to saturation vapor pressure at the same temperature, expressed as percentage.

Since that RH inside a fruit is considered as 100%, when RH surrounding the commodity is lower, transpiration and water loss will occur, thus causing wilting, shriveling and quality loss. The lower the RH surrounding the fruit, the higher the rate of water loss, and the faster will be the deterioration of the product. Recommended RH is 85-90% for fruits, 90-95% for vegetable (except dry onions and garlic 65-70%).

Water loss decreases very significantly by decreasing the temperature, indicating another important positive effect of cooling and crop quality as instance, in fast cooling and waxing some horticulture commodities.

**Factors affecting water loss**
**Commodity factors**. Surface to volume ratio of horticultural crops influence the velocity of water loss. For example, water loss is very high in lettuce which has high surface to volume ratio. Anatomy and evaporative surface of the different horticultural crops also influence water loss. The structure and components (such as the extent of cuticular waxes) of horticultural crops also has a profound effect on the velocity of water loss e.g. pumpkins has low rate of water loss (witting) due to thick waxy peel, while carrots wilt rapidly at ambient temperature due to lack of protective layer (cells are naked).

**Environmental factors**. Relative humidity and temperature are the most important factors influencing the velocity of water loss. The higher the temperature and/or the lower the relative humidity, the higher will be the water loss.

**Control of relative humidity**
1. Add moisture to air by humidifiers: water mist, spray or steam.
2. Regulate air movement and ventilation.
3. Maintain refrigeration coils in cold rooms within 1°C of the air temperature.
4. Provide moisture barriers, polyethylene liners, plastic films, waxing, etc.
5. Add crushed ice to produce.
6. Sprinkling produce with water.
7. Wetting floors in storage rooms (not very effective).

**Methods and technologies for reducing water loss**

Control of water loss is very important to reduce quality deterioration and losses of horticultural crops. Some of the important techniques and methods commonly used include:

- **Refrigeration**. Low temperature and high relative humidity in cold stores are the most effective means for reducing water loss.
- **Packaging**. The use of different packages, especially of ventilated plastic, can serve as vapor barrier and can reduce water loss.
- **Waxing**. Several fruits and vegetables (such as citrus, cucumber, tomatoes) are waxed to increase the resistance of water diffusion and to reduce water loss. Waxing can also modify the internal atmosphere of the commodity.
- **Curing**. Some crops such as potatoes and sweet potatoes are cured to increase the synthesis of suberized cells on the surface, and therefore to increase water diffusion and decrease water loss.

Figure 1. Using of plastic liners helps reduce water losses (U.C. Davis).

Figure 2. Waxing reduces water losses (USDA).

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# MATURITY AND QUALITY INDICES

Timing of harvest based on maturity indices is very important. Crops harvested before optimum maturity may not ripen adequately and may not develop adequate flavor, while crops harvested late (over-mature) will have a shorter postharvest life and will deteriorate easily.


Figure 1. Ripening stages in lemon (Courtesy of Dr. Luz Marina Carbajal).

Climacteric crops can be harvested after reaching full maturation, and before reaching the ripening stage. However, non-climacteric crops will not ripen off the plant and therefore they should be harvested when they reach their ideal eating quality (ripening stage). All fruits (with few exceptions such as avocados, bananas and Bartlett pears) reach their optimum quality on the tree. Several vegetables, such as leafy vegetables (lettuce) and immature fruit vegetables (cucumbers, sweet corn, green beans, peas) reach their optimum quality before full maturity.

**Quality** is defined in the Oxford dictionary as ".... degree of excellence. Quality is due to a wide range of attributes, which can also be used as maturity indices, such as:

1. Size: dimensions, weight, volume.
2. Shape: diameter, length, compactness.
3. Color: uniformity, intensity.
4. Gloss: wax of cuticle.
5. Absence of defects: morphological, physical, physiological, pathological, insects, etc.
6. Texture: firmness.
7. Flavor: Sweetness, aroma, absence of off-flavors and off-odors.
8. Nutritional factors: phyto-chemicals, vitamins, antioxidants, etc.

Figure 2. Measurement of size in banana (U.C. Davis).

**Requirements for maturity/harvesting indices**:

1. Indices should relate to maturity, quality and postharvest life.
2. Measurements should be simple, can be carried out in the field, and should not require expensive equipments.
3. Indices should preferably be objective rather than subjective, and also should preferably be non-destructive.
4. Good indices should not be affected by geographical location.

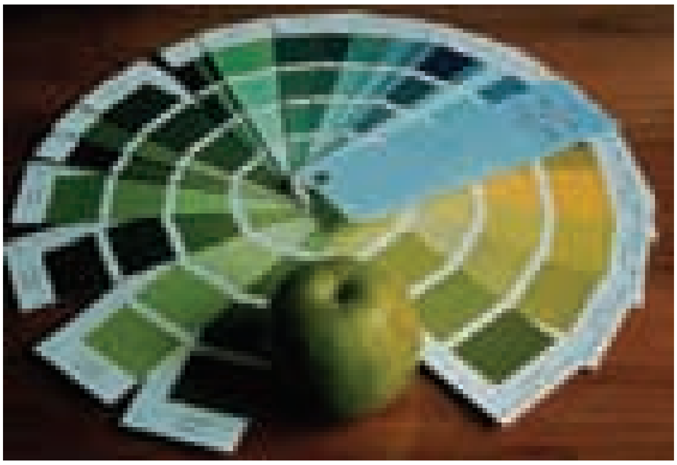

Figure 3. Color charts (UC Davis)

Figure 4. Pressure testing for measuring firmness (Dr. Elhadi Yahia).

Figure 5. Color measurements in apples (UC Davis).

**Table 1.** Maturity indices of selected fruits and vegetables.

| Index | Examples of crops |
|---|---|
| Elapsed days from full bloom to harvest | Apples, pears |
| Mean heat units during development | Peas, apples, sweet corn |
| Size | All fruits and many vegetables |
| External color | All fruits and most vegetables |
| Internal color | Some cultivars of mango |
| Shape | Banana (angularity), mango (full cheeks), broccoli/cauliflower (compactness) |
| Firmness | Apples, pears, stone fruits |
| Tenderness | Peas |
| Development of abscission layer | Some melons, apples, |
| Surface morphology and structure | Melons (netting), grapes (cuticle) |
| Specific gravity | Cherries, watermelon, potatoes |
| Solidity | Lettuce, cabbage, Brussels sprouts |
| | |
| **Compositional factors** | |
| Total soluble solids (sugars) | Grapes, citrus fruits, stone fruits |
| Acids content | Citrus fruits, grapes |
| Sugar/acid ratio | Citrus fruits, pomegranate |
| Starch content | Apples, pears |
| Oil content | Avocados |
| Astringency (tannin content) | Persimmons, dates |
| Internal ethylene content | Apples |

**Maturity vs. quality factors**:
Most maturity indices are also quality indices, but some quality indices are not maturity indices.

**Methods of measuring quality and maturity indices**
**Subjective methods**
External color: visual
Size: visual
Elapsed days from full bloom: computation
Heat units: weather data
Development of abscission layer: visual
Solidity: feel

**Objective methods**
**Size measurements**
Weight: balance
Specific gravity: density gradient solutions, flotation techniques (vol/wt).
Shape: measurements of length, circumferences.
Solidity: x-rays
Total soluble solids (sugars): Refractometers
Color: visual color charts, colorimeters, light reflectance
Texture: pressure testers
Tenderness: Tenderometers
Toughness: texturometer, fibrometer, analysis of polysaccharides.
Starch content: KI (potassium iodine) test
Acids content: titration
Juice content: extraction

Oil content: extraction, chemical analysis
Tannin content: ferric chloride test
Internal ethylene content: gas chromatograph

**Standardization and inspection**
**Quality standards** are valuable tools to:

- Establish a common language among growers, handlers, processors, traders, receivers, etc.
- Serve as a base for market and price reporting.
- Settle disputes and claims among producers, buyers, sellers, etc.

**Types of standards**
There are many types of standards for horticultural crops in different countries. Several organizations are responsible for establishing such standards. For example, the European Commission is responsible for establishing standards and regulations for commodities handled in Europe. In addition, individual countries in Europe may have their own standards and regulations. The Organization for Economic Cooperation and Development of the United Nations, and the International Organization for Standardizations (both in Geneva, Switzerland) are also involved in development of standards.

Figure6. Quality evaluation of oranges in Morocco (Dr. Elhadi Yahia)

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# ETHYLENE

Ethylene ($C_2H_4$) gas has a profound effect on fresh horticultural crops. $C_2H_4$ is the simplest chemical compound known to cause a significant physiological effect in plants, and the only known plant hormone in the form of gas.

**Characteristics**

- A gas produced naturally by all plants and some other organs.
- Causes ripening/aging/senescence of plant tissues.
- Acts at very low concentrations (ppm, ppb).
- Low temperature decreases its production and action.
- High temperature (< 35°C) increases production and action, but higher temperatures inhibits its synthesis and action.
- Stress (physical damage, decay, etc) increases its production.

Figure 1. Ethylene causes yellowing (as shown in the product in the left hand side) of broccoli (U.C. Davis)

**Negative effects of ethylene**

- Accelerates ripening/aging/senescence, and therefore causes shorter postharvest life of horticultural crops.
- Causes color (pigments) breakdown (chlorophyll) or development (carotenoids, anthocyanins).
- Accelerates softening of tissues.
- Enhances decay.
- Causes abscission of flowers, leaves and fruits.
- Causes some off-flavors (bitterness) such as in carrots.
- Causes several physiological disorders such as russet spotting in lettuce, toughness of asparagus, and sprouting in potato.
- Flammable/explosive at concentrations of 3.1 to 32% by volume.

**Positive effects of ethylene**

- Accelerates fruit ripening such as in bananas (Figure 3) and tomatoes.
- Promotes color development such as in citrus (degreening), tomatoes, and bananas.
- Causes abscission and thus facilitates harvesting.


Figure 2. Ethylene causes yellowing of Cucumber (U.C. Davis).

**Biosynthesis**

Ethylene can be synthesized from many chemical compounds, but it is believed that the *in vivo* physiological biosynthesis starts with the amino acid methionine, which is activated with ATP (energy) to produce SAM (S-adenosyl methionine). This reaction is catalyzed by the enzyme SAM synthatase. SAM is then transformed by ACC synthase to produce ACC (aminocyclo propane carboxylic acid). ACC is catalyzed by ACC oxidase to produce ethylene in the presence of oxygen. Anaerobic conditions (100% $N_2$) causes the accumulation of ACC and prevents the production of ethylene.

Figure 3. Ethylene enhance ripening of banana (U.C. Davis).

Figure 4. Banana ripening rooms (by using ethylene)

Figure 5. Interior of a banana ripening room (Dr. E.M. Yahia).

**Ethylene production**

Some fruits produce more ethylene than others. Climacteric fruits usually produce more ethylene than non-climacteric fruits. Ethylene produced by one fruit can act on another fruit near by sensitive to Ethylene gas and causes its ripening and senescence. Ethylene production and action can be reduced very significantly at low temperature.

Table 1 summarizes the different groups of fruits in relation to ethylene production.

**Table 1.** Classification of horticultural crops according to their ethylene production (µl/kg.hr) at 20ºC.

| Class | Production | Commodities |
|---|---|---|
| Very low | Less than o.1 | Artichoke, asparagus, cauliflower, cherry, citrus, grape, jujube, strawberry, pomegranate, leafy vegetables, root vegetables, potato, most cut flowers |
| Low | 0.1-1.0 | Blackberry, blueberry, casaba melon, cranberry, cucumber, eggplant, okra, olive, pepper, persimmon, pineapple, raspberry, watermelon |
| Medium | 1.0-10 | Banana, fig, guava, honeydew, melon, mango, plantain, tomato |
| High | 10-100 | Apple, apricot, avocado, cantaloupe, kiwifruit, nectarine, papaya, peach, pear, plum |
| Very high | More than 100 | Cherimoya, passion fruit, sapote |

**Action**

As a plant hormone, ethylene initiates its action through the binding with a receptor protein.

**Control**

There are several means to control the negative effects of ethylene, including physical and chemical methods. Low temperature can reduce both ethylene production and action. The optimum temperature for Ethylene production is (18-25ºC). Temperatures above 35ºC inhibit ethylene production. For chilling sensitive crops, chilling temperatures can increase ethylene production. Modified and controlled atmospheres significantly reduce the undesirable effects of $C_2H_4$. Several chemicals can effect either the production or the action of ethylene. For example, silver thiosulfate (STS) is widely used in the flower industry to inhibit ethylene action and to prolong the shelf life of cut flowers. 1-MCP is another chemical introduced recently for several crops, which inhibits ethylene action, and prolongs postharvest life in some products.

**Promotion of fruit ripening and color**

Ethylene is widely used to initiate or accelerate fruit ripening in several fruits such as banana and tomatoes. It is also commonly used to improve color development in fruits such as oranges (especially those grown in the tropics where orange color is commonly not produced). The process of color enhancement is called “de-greening”.

Optimum conditions for the initiation and acceleration of fruit ripening or de-greening include a temperature of 17-25ºC, high relative humidity (90-95%), 5-100 ppm $C_2H_4$, sufficient air circulation for temperature and gas uniform distribution in the room, adequate air ventilation to eliminate the accumulation of $CO_2$ in the room.

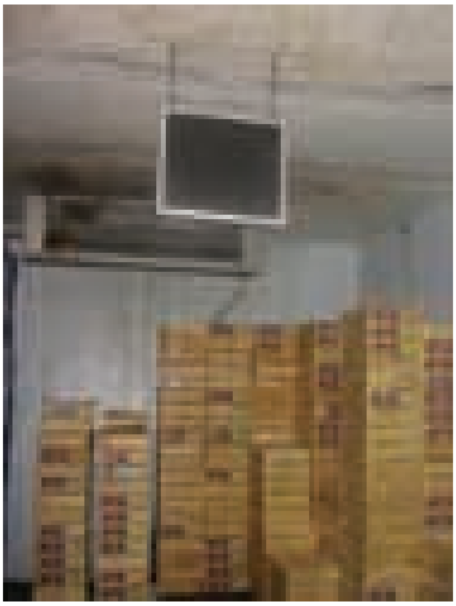

Figure 6. Absorption (elimination) of ethylene in a storage room (Dr. E.M. Yahia).

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# PRE-HARVEST FACTORS AFFECTING POSTHARVEST QUALITY

Several factors before harvest affect quality of horticultural crops after harvest. Some of these factors are related to the plant, others are related to the environment or to cultural practices.

**Cultivars**. The quality of the seed or the plant material is an important factor affecting the quality of the fruit produced. Several parameters of quality are controlled genetically.

**Cultural practices**. All cultural practices have direct effect on the final quality of the horticultural commodities.

**Seeding or planting period**. Many plants are very sensitive to environmental conditions, and thus quality will not be optimized when crop is produced under adverse conditions. Producing summer plants during the winter or vice versa will not be appropriate, unless protection practices are implemented.

**Planting density**. Planting density will affect both the quantity and quality of the produce. High density planting increases competition between plants, reduces light availability, and thus may decrease quality. Low density plantings usually lead to large size, better colored fruit or vegetable, which may have shorter shelf life. Larger fruits are generally more sensitive to physiological disorders.

**Irrigation**. Irregular watering usually reduces fruit size, increases splitting, physiological disorders, reduces water content in the plant or plant part.

**Fertilization**. Poor management of fertilizers will increase physiological disorders due to deficiencies of some minerals, wherever, increase of others leading to toxicity. In both cases quality will be negatively affected.

**Pruning**. Pruning reduces the load and increases the growth of fruit (increasing size) and chemical use after harvest.

**Thinning**. This operation reduces the competition between fruits or plants, and thus promotes a good balance between the vegetative and fruit parts, and improves size and quality.

**Protection from pests and diseases**. Pathogens and insects have a very negative effect on quality. Poor management of plant protection programs can lead to very poor quality and reduced yield and increase pre and postharvest losses.

**Environmental factors**. Temperature is the most important environmental factor that affects quality of horticultural crops. Very low or very high temperatures may injure sensitive crops. Chilling injury and heat injury respectively, adequate light intensity and light quality is important for the formation of some pigments (colors). Wind and rain may cause negative effects on some crops.

**Chemicals**. Many hormones and growth regulators are used in agriculture and they can affect quality in different ways; positive or negative.

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# RESPIRATION

Fresh horticultural crops are live organs, which respire continuously on and off the plant. Respiration is the oxidative process (using $O_2$) of converting organic materials such as carbohydrates, organic acids and lipids, into simple compounds ($CO_2$) with the concomitant release of energy.

During respiration horticultural crops commonly use hexose sugars as substrates, however they can also use other substrates such as organic or fatty acids, and in the process the substrate is oxidized by $O_2$ and degraded to $CO_2$, and heat is produced, referred to as “vital heat” or “heat of respiration”.

“Vital heat” is very important from the stand point of cooling, designing of refrigeration equipments and packaging materials. The faster the product respires, the more heat it generates and the warmer it will be, unless it is cooled adequately.

Respiration is a direct measure of postharvest or storage life. Products that respire very fast are classified as very perishable, and generally have a shorter postharvest life than those that respire slowly.

**Table 1.** Classification of some horticultural crops according to their respiration rate (mg $CO_2$/kg.hr. at 5°C).

| **Class** | **Respiration rate** | **Commodities** |
|---|---|---|
| Very low | < 5 | Dates, dried fruit and vegetables, nuts |
| Low | 5-10 | Apples, beets, celery, cranberry, garlic, grapes, honeydew melons, citrus fruits, kiwifruit, onions, papaya, persimmon, pineapple, potato, sweet potatoes, water melons |
| Medium | 10-20 | Apricot, bananas, blueberry, cabbage, cantaloupe, carrots (topped), celeriac, cherry, cucumber, fig, lettuce, mango, nectarine, olive, peach, pear, plum, summer squash, tomato |
| High | 20-40 | Avocado, blackberry, cauliflower, leeks, lettuce, lima bean, radish, raspberry |
| Very high | 40-60 | Artichoke, bean sprouts, broccoli, Brussels sprouts, cut flowers, green onions, okra, snap bean, watercress |
| Extremely high | > 60 | Asparagus, mushroom, parsley, peas, spinach, sweet corn |

**Table 2.** Respiration rate at 15°C and potential postharvest life of some horticultural crops at optimum temperature.

| **Crop** | **Respiration rate** mL $CO_2$/kg.hr. at 15°C | **Postharvest life** Weeks or days |
|---|---|---|
| Potato | 8 | 16-24 wks |
| Grapes | 16 | 4-16 wks |
| Lemon | 20 | 4-8 Wks |
| Orange | 20 | 6-12 wks |
| Apples | 25 | 8-30 wks |
| Cabbage | 32 | 4-8 wks |
| Carrots | 45 | 12-20 wks |
| Green banana | 45 | 4-6 wks |
| Peach | 50 | 2-6 wks |
| Strawberries | 75 | 1-5 days |
| Lettuce | 200 | 1-2 wks |
| Ripe banana | 200 | 3-4 days |
| Bean | 250 | 1-3 wks |
| Peas | 260 | 1-3 wks |

**Factors affecting respiration**

There are several factors that affect the respiration rate of horticultural crops, and consequently affect the potential postharvest life. Some of these factors are internal such as variety and maturity stage at harvest, but the most important factors are the external factors, especially the environmental conditions such as temperature, humidity and atmospheric gases ($O_2$, $CO_2$, $C_2H_4$, CO).

**Temperature Quotient, ($Q_{10}$), Van´t Hoff ´s law**

For every increase of 10°C in temperature, the biological activity or chemical/biochemical reactions (such as respiration rate) increases 2 to 4 folds. For example, If we assume that the optimum holding temperature for a fruit is 0°C, its deterioration rate at 0°C = 1, its postharvest life at this temperature is 30 days, and its Q10 at this temperature 3 (although Q10 is not constant at different temperatures), then its postharvest life can be as follow (considering that other factors are constant):

| **Temperature** | **Biological activity** | **Deterioration rate** | **Postharvest life** |
|---|---|---|---|
| 0°C | | 1x | 30 days |
| 10°C | 3x | 3x | 10 days |
| 20°C | 9x | 9x | 3.3 days |
| 30°C | 27 | 27x | 1.1 days |
| 40°C | 81 | 81x | 0.4 day |

This example shows the profound effect of temperature on the postharvest life of fresh horticultural products. Temperature also has a very profound effect on quality of these products.

**Significance of the respiration process**

The process of respiration is very significant for the handling of fresh horticultural crops. It determines metabolic activity and therefore the postharvest life of these crops, the extent of the loss of organic (reserve, dry matter) materials, loss of flavor components, production of energy, and heat, and aging and senescence of the tissue.

Horticultural crops are commonly divided, according to their process of respiration into 2 classes:

**Climacteric crops**: those that are characterized by a sudden increase (climax) in their respiration activity, which coincides with the initiation of the process of maturation and ripening. Examples of climacteric crops include apple, apricot, avocado, banana, fig, guava, kiwifruit, mango, muskmelon, nectarine, papaya, passion fruit, peach, pear, persimmons, plantain, plum, tomato and cut flower such as carnation.

**Non-climacteric crops**: are those that do not present a sudden increase in their respiration activity. Examples of non-climacteric crops include blackberry, cacao, carrot, cashew, cherry, cucumber, date, eggplant, grape, grapefruit, lemon, lime, loquat, okra, olive, orange, pea, pepper, pineapple, pomegranate, potato, prickly pear, raspberry, strawberry, summer squash, mandarin, watermelon.

Non-climacteric products do not ripen after harvest and therefore they should be picked when they are fully ripened. However, climacteric crops can be ripened after harvest either naturally or artificially and therefore they can be picked before they are completely ripe (after they achieve their physiological maturation) and can be ripened after harvest. This is advantageous from the standpoint of long distance transport of horticultural crops, where less ripe crops can tolerate handling. Climacteric crops generally produce more ethylene than the non-climacteric crops.

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# HARVESTING

**When to harvest?**

The time (early or late in the season) for harvest is usually a compromise due to different factors such as prices, handling, type of product (climacteric or no climacteric), consumer acceptance and form of consumption (fresh or processing), marketing and type and distance of the markets, type of harvesting (manual or mechanical), etc. However, there are minimum requirements that should be considered including maturity/ripening of the crop, minimum quality standards, and consumer acceptance.

**Types of harvesting methods**

**Hand harvesting**. Most horticultural crops intended for the fresh consumption are picked by hand. This method reduces mechanical damage of the commodity; however it is slow and can be expensive when labor is short and/or expensive. Hand harvesting is selective and can be done several times.

Figure 2. Manual harvesting (bean harvesting is courtesy of Dr. Rawi Basiouni)

**Assisted harvesting**. These methods use several tools such as knifes and clippers. Chemical aids such as ethephon can be used in some products such as olives and nuts. Non-chemical and mechanical aids (ladders, picking baskets, motorized harvesting platforms and man-movers) are also common during harvesting of crops such as dates, citrus and nuts.

Figure 3. Harvesting of grapes (courtesy of Dr. Rawia Basiouni).

**Mechanical harvesting**. Some crops are harvested mechanically, such as nuts and some crops intended for processing (such as tomatoes). Mechanically harvested crops are commonly damaged and easily decayed and machines usually have high unit cost. Mechanical harvesting is done only once, and therefore harvested product may not be uniform (in ripeness, size, color, etc) when harvested.

Figure 4. Mechanical harvesting of nuts (U.C. Davis).

**Mechanical injury**

This is the major problem causing losses during harvesting, especially mechanical harvesting. Mechanical (physical) injury increases water loss, shriveling, losses of some important components such as vitamins, increase respiration rate, increase production of ethylene, facilitates infection with micro-organisms, and quality deterioration.

**Other important factors**

Harvesting is recommended to be done during cool hours of the day to reduce field heat, and the refrigeration capacity. Harvested crop should be maintained in a shaded area until it is transported to the pre-cooling or packing facility, or transported to the market. Maintaining the crop in a hot spot can significantly increase its deterioration, and reduces its life. The harvested crop should be transported as soon as possible to the pre-cooling or packing facility.

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# PRE-COOLING (RAPID COOLING) AND REFRIGERATION

Temperature control is the most important postharvest technique for the preservation of fresh horticultural crops. All the other treatments and techniques used in postharvest, including use of chemicals, irradiation, modified and controlled atmospheres, etc, can only serve as supplements to refrigeration. Generally, the lower the temperature around fresh horticultural crops the lower the deterioration rate, and the higher the temperature the faster the deterioration rate and the higher the losses.

**Sources of heat**

When a product is cooled there are several sources of heat that need to be eliminated:

1. **Field heat**: is the heat brought by the product from the field, and has to be extracted or removed immediately after harvest.
2. **Vital heat**: is the heat generated as a natural by-product of respiration.
3. **Heat of conduction**: is the heat entering to the store or refrigerated container through walls, ceiling and floor.
4. **Heat of convection**: is the heat entering the store or refrigerated container through open spaces (such as doors, cracks).
5. **Others**: such as the heat generated by lights, equipments and people.

**Ton of refrigeration capacity**: is the amount of heat absorbed by or required to melt a ton of ice at 0°C in 24 hours. It requires 144 BTU (British Thermal Unit) to melt 1 pound (Lb), or 288,000 BTU to melt one ton of ice at 0°C (144 BTU x 2000 Lb). BTU /ton/day = mg $CO_2$/kg.hr x 220.

Table 1 Shows an example of the refrigerated capacity needed to cool an early or late harvested potato crop.

**Table 1.** Cooling of potato.

| | **Early crop** | **Late crop** |
|---|---|---|
| Harvest | August 1st | September 15th |
| Harvest temperature | 29°C | 24°C |
| Storage temperature | 7°C | 7°C |
| Tons (12,000 BTU/hr) of refrigeration: | | |
| Field heat | 12.4 | 9.0 |
| Respiration | 6.0 | 2.6 |
| Others | 5.7 | 3.7 |
| Total | 24.1 | 15.3 |

Source: Bartsch and Blanpied (1984).

Refrigerated capacity is lower when the crop is harvested at lower temperatures.
Field heat is usually a large amount of heat as compared to other types of heat, and therefore it can not be eliminated easily and rapidly by a regular refrigeration system in a cold store, much less by a refrigerated transport container.

**Pre-cooling (rapid cooling):** is the rapid removal of field heat.

**Advantages of cooling**

- Reduces respiration (less perishability).
- Reduces transpiration (reduced water loss, and shriveling).
- Reduces ethylene production.
- Increases resistance to ethylene action.
- Decreases activity of micro-organisms.
- Delays ripening and senescence.

**For example: effect of temperature on decay organisms**

Ideal temperature for development of most pathogens is 20-25°C. Low temperature decreases the activity of micro-organims. Some organisms do not grow at low temperature. For example *Rhizopus* decay ceases at 5°C, and at -1 to 0°C only a few fungi can grow.

**How fast "rapid cooling" should be applied?:**

- For very perishable commodities such as flowers, strawberries, grapes and lettuce: very fast, 1-3 hours from harvest.
- For less perishable products such as mango: within 24 hours from harvest.
- There are some commodities such as citrus, potatoes, sweet potatoes, onions, garlic and bananas that are not commonly pre-cooled.

The postharvest "Golden Rule" is: **"Cool it fast and keep it cool"**. This includes pre-cooling and constant refrigeration at optimum temperature.

**Pre-cooling methods:**

- Room cooling
- Forced (pressure) air cooling
- Hydro-cooling
- Vacuum cooling, hydro-vacuum.
- Evaporative cooling.
- Contact/package/top icing

**Room cooling**

- Product, packaged or not, is exposed to cold air in a regular cold store.
- It is a slow pre-cooling process (low cooling rate), which usually takes 24 to 72 hours. Air normally passes only around the packages, and not in contact with the commodity.
- Lower cost, compared to other methods.
- Air velocity should be at least 60-120 m/min.
- Adequate packages/stacking is needed for better cold air flow.
- All commodities can be pre-cooled by room cooling, but not adequate for very perishable crops, such as flowers and strawberries.

Figure 1. Room cooling. When cooling is used in cooling rooms enough space between pallets should be maintained to allow passage of cool air.

**Forced-air cooling**:

- This method creates a pressure gradient on opposite ends, and thus forces air through the stack. In this system a large volume of cold air is used, and air velocity is increased.
- Cold air is forced to pass through the container, passing through the product and contacting it.
- Cooling is 4 to 10 times faster than room cooling, but initial cost is higher.
- Commodities that can be cooled by this method are those perishable crops that are not water tolerant such as flowers, strawberries, grapes, berries, tomatoes, avocados, and mangoes.

Figure 2. Passage of cool air when using forced-air cooling (U.C. Davis).

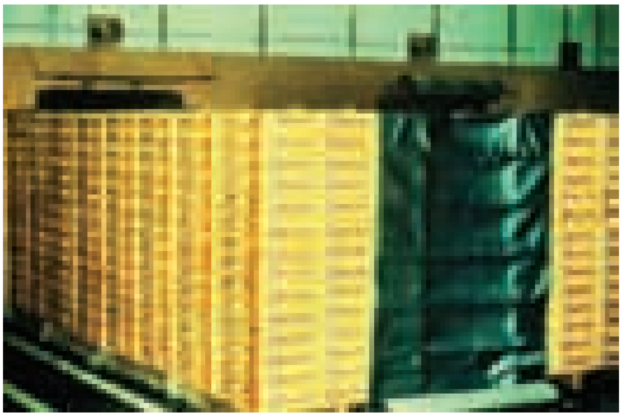

Figure 3. Forced-air cooling.

**Hydro-cooling**
Is the use of cold water for cooling. This system is characterized by rapid cooling (faster than air), and causes less water loss from commodities. Product and packages must tolerate water, and the water must be disinfected and cleaned regularly to avoid contamination. Products that can be hydro-cooled include peaches, carrots, cantaloupe, and sweet corn, among others.

**Vacuum cooling**:
Cooling by this method involves boiling off some water in the commodity at low pressure. Water boils at 100°C at 760 mmHg, but when pressure is reduced the temperature at which water boils is also reduced. For example at a pressure of 660 Pascals (5 mmHg) water boils at 1°C. Water loss from the lettuce is about 1% for every 6°C (11°F) reduction. When water loss is excessive hydro-vacuum cooling can be utilized. Rate of cooling is dependent on surface/volume ratio of the product. For example it is very fast in products with high surface: volume ratio such as lettuce, and very low in products with low surface: volume ratio such as fruits. Initial cost for this method is high.

**Evaporative cooling**:
- Air is cooled with evaporative cooler, with no mechanical refrigeration.
- Cooling is obtained with humidified cold air or misting.
- Cooling rate is limited.
- It is a simple process with low energy cost.
- This method can be adapted for regions with low relative humidity (< 65%) and good quality water supply. It can be adapted for chilling sensitive crops.

**Contact/package/top icing**:
- Cooling can be done using finely crushed ice, or ice slurry containing liquid ice, 40% water, 60% ice, and 0.1% salt.
- This method is commonly used during transit, but it results in slow and limited cooling. For example, cooling of a crop from 35°C to 2°C require 38% of the total load weight being ice. It is recommended that this method be used as a supplement to other pre-cooling methods. Commodities that can be ice cooled are those that tolerate ice and water such as spinach, broccoli, radishes, green onions, sweet corn.

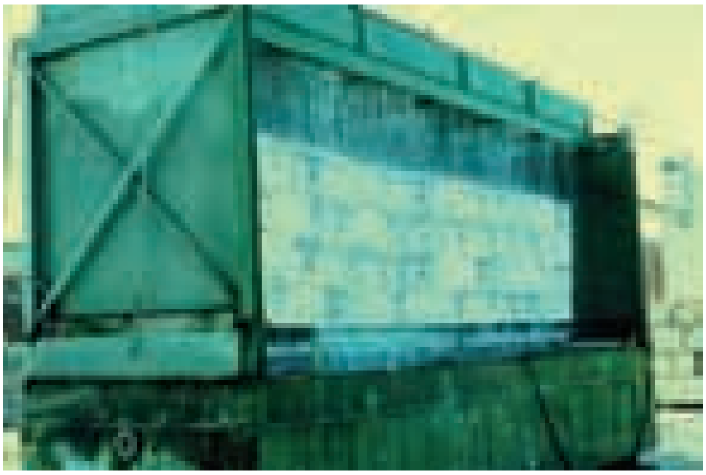

Figure 4. Hydro-cooling.

Figure 5. Hydro-cooler.

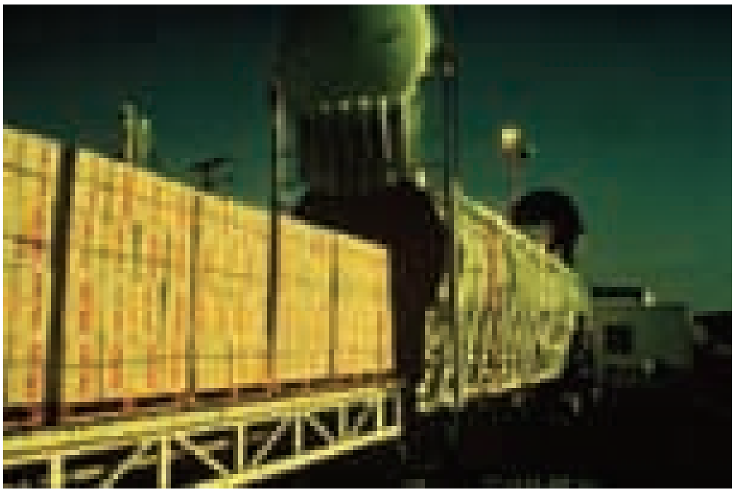

Figure 6. Vacuum cooler.

**Refrigeration**
**Site selection for refrigerated rooms**
Several factors should be considered:

**Drainage**. Site should be well drained.
**Design**: refrigerated room should be one story level. Rooms with more than one story level are difficult to manage, expensive to operate, and cooling and quality of produce will commonly be poor.
**Expansion**. Possible future expansion should be taken into consideration.
**Structural considerations**. Several designs are used for cold stores. Steel buildings are used, especially for refrigerated controlled atmosphere rooms. Concrete blocks are commonly used.

**Thermal insulation**. Type and material of thermal insulation must be selected adequately to provide adequate temperature control. Cold rooms operated in warm areas should be designed with higher thermal insulation values (R). Higher R values (resistance to heat flow) indicate greater resistance to heat flow and better insulating characteristics. The R values of several insulating materials are shown in Table 2.

Figure 7. Application of crushed ice.

**Table 2.** Examples of R values of some insulating materials.

| Material | R values ($m^2$ °K)/W |
|---|---|
| Loose fibreglass | 0.177/cm |
| Board fibreglass | 0.277/cm |
| Cellular glass | 0.198/cm |
| Extruded Styrofoam | 0.346/cm |
| Polyurethane (board) | 0.433/cm |
| Polyurethane (foamed in place) | 0.433/cm |
| Polyisocyanurate (board) | 0.488/cm |

Source: Bartsch and Blanpied (1984).

**Vapor barriers**

Moisture accumulation in the room structure will deteriorate thermal insulation and may even cause structural damage due to rotting and rusting. Vapor barriers are important to prevent moisture accumulation. Materials such as 6 mil (0.001 inch) polyethylene are commonly installed, especially at the warmer side of the cold room.

**The mechanism of refrigeration**

Refrigeration uses refrigerants to absorb heat. Heat from inside the cold room is absorbed due the change of phase of the refrigerant. The liquid refrigerant is accumulated in a receiving tank (located outside the room) at high pressure, and will flow as needed and boils in the evaporator (located inside the room) under low pressure. Here heat is absorbed by the evaporating refrigerant resulting in cooling the air in the room, and thus the stored commodities. The cold low pressure vapor is compressed (compressor is located outside of the room), and this hot compressed vapor is condensed and converted to liquid again, which is accumulated again in the receiving tank to flow when needed.

**Importance of air circulation during refrigerated storage and transport**

1. Continuously dissipate heat produced by the product.
2. Maintains temperature uniformly low in all parts of the cold store or the container, and avoids the build-up of hot spots.

3. Eliminates the build-up of gases (ethylene, $CO_2$) in the cold store or the refrigerated container.

**Types of air circulation**

Top (horizontal) air delivery is common in refrigerated cold rooms and in refrigerated trucks. Bottom (vertical) air delivery is common in marine containers.

**Package designs and stacking systems**

Packages should be designed to facilitate cooling of the product, and should be stacked in a manner that permits the free circulation of cold air within the container or the refrigerated store.

**Humidity maintenance in store**

Most horticultural crops require high relative humidity (% RH) during storage and transport. Water loss and shriveling (and thus quality deterioration) can be reduced very significantly at low temperature and high relative humidity. High RH in store can be established by maintaining the least temperature difference between the outlet and inlet of the evaporator. For example in a cold room operating at 0°C a temperature difference of 1°F provides a RH of 95.8%, a difference of 3°F provides a RH of 87.1% and a difference of 10°F provides a RH of 62.7%. Increasing humidity in the store is also effective with the use of humidifiers.

**Sanitary conditions in storage rooms and transport containers**

Sanitary conditions and hygiene are essential to minimize development of contamination by decay organisms. This can be achieved by:

- Good air circulation.
- Clean-up floors, walls, ceiling, boxes, and equipments when rooms are empty.
- Rinse with sodium hypochlorite, trisodium phosphate.
- One liter of household chlorine bleach/20 liters water will provide a 0.25% solution of sodium hypochlorite.
- Use of fungicide paint.
- Clean boxes and equipments with 0.25% calcium hypochlorite solution, or expose to superheated steam for 2 minutes.
- Purification to eliminate off-odors using trays or canisters of 6-14 mesh activated coconut-shell carbon.
- Ozone can be used to reduce surfaces moulds on walls and containers.

**Mixed loads**

Many horticultural crops are stored and transported together in mixed loads. Mixing loads should be done in a manner that would not cause injury and loss of some of the crops.

**Table 3.** Classification of horticultural crops according to their relative perishability and potential postharvest life (weeks) at optimum temperature.

| Perishability class | Postharvest life | Commodities |
|---|---|---|
| **Very high** | < 2 wks | Apricot, blackberry, blueberry, cherry, fig, rasberry, strawberry, asparagus, bean sprouts, broccoli, cauliflower, cantaloupe, green onion, lettuce, mushroom, peas, spinach, sweet corn, ripe tomato, most cut flowers and foliage, minimally processed fruits and vegetables. |
| **High** | 2-4 wks | Avocado, banana, grape (without $SO_2$ treatment), guava, loquat, mandarin, mango, honeydew melon, Persian melon, nectarine, papaya, peach, pepino, plum, artichoke, green beans, Brussels sprouts, cabbage, celery, eggplant, okra, pepper, summer squash, ripe tomato. |
| **Moderate** | 4-8 wks | Some cultivars of apple and pear, grape ($SO_2$ treated), orange, grapefruit, lime, kiwifruit, persimmon, pomegranate, pummelo, table beet, carrot, radish, potato. |
| **Low** | 8-16 wks | Some cultivars of apple and pear, lemon, mature potato, dry onion, garlic, pumpkin, winter squash, sweet potato, taro, yam, bulbs and propagules of ornamental plants. |
| **Very low** | > 16 wks | Tree nuts, dried fruits and vegetables |

Figure 8. Refrigerated room (Dr. Elhadi Yahia).

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# QUALITY CONTROL

A quality control system should be implemented during production and handling of horticultural crops. Quality of fresh horticultural commodities is a combination of several attributes that ensure satisfaction of the consumer. The quality is defined by many objective and subjective parameters, which are used following the destination of the product. A good quality for processing, or storage is not automatically a suitable quality for immediate consumption. Quality parameters of fresh fruits and vegetables include various criteria which are used for sorting and grading of the commodities.

Preharvest practices of fruits and vegetables production are aimed to ensure good yield with good quality products free from defects that can reduce its acceptability.

Many factors used in quality assessment and safety measures are becoming most important factor for quality assurance and control.

External appearance is an important quality criterion and includes several parameters such as color, size and shape, which are specific to the commodity. Appearance can be affected by morphological defects such rooting, sprouting, rusting, curvature, misshape. Physical defects concern wilting, shriveling, drying and mechanical defects are caused by bruising, skin cuts, and skin cracks. Physiological disorders include chilling injury symptoms, sun burn, and other disorders related to storage conditions (raise $CO_2$ damage, reduce $O_2$ damage, Ethylene damage and Ammonium damage). The appearance is also affected by pathogens, insects, birds and rodents.

For handling, transport and storage fruit and vegetable texture is very important so that the product can withstand different operations without major damage. Very soft products are easily damaged during harvesting, transport or packing.

Other factors include flavor components such as sweetness, acidity, astringency, aroma, off-flavors and off-odors. Nutritive values of the consumed produce, which is composed of carbohydrates, proteins, lipids, vitamins, minerals and phytochemicals, are essential for quality of both fresh and processed products.

**Good harvesting and handling practices**

Postharvest quality management for horticultural crops starts from the field. Good practices of harvesting and handling are required.

During harvest, the workers must take all the necessary precautions to reduce damages to the crop. Mechanical damage can be caused by workers fingers, cuts by scissors, cutters, ladders, compression, crushing, and bruising. Causes of mechanical damage must be controlled and avoided in the field and during transport and handling.

Inspection of fruit quality before shipping and at arrival (Dr. Elhadi M. Yahia).

**Quality control**

At arrival to the packinghouse or processing plant, quality inspection should be performed. Samples of produce should be inspected and rated according to the desired parameters (size, color, appearance, maturity, freedom from defects, decay, sanitation and safety). Assessment of the quality is performed using subjective and objective methods. The quality control at arrival before packing or processing is very important and saves time and reduces cost during the other operations. The operation requires well trained staff for the quality control and assessment.

Handling horticultural crops for both fresh and processing requires verification and control of the main operations that can affect the final quality. This is known in processing as the critical points or operations, which will affect directly the final quality if any mistake is made. Preventing the mistakes is the basis of the HACCP (hazard analysis and control of critical points) concept. The control of each critical point such as inspection and sorting, pre-treatments and preparation, ingredient formulation and preparation, processing, packaging and distribution, etc, can reduce the problems related to production and handling. The implementation of HACCP requires the following steps:

1. Assemble a HACCP team.
2. Describe the product.
3. Identify the intended use.

4. Construct the flow diagram.
5. On-site confirmation of flow diagram.
6. List all potential hazards, conduct hazard analysis, and consider control measures.
7. Determine Critical Control Points (CCPs).
8. Establish critical limits for each CCP.
9. Establish monitoring system for each CCP.
10. Establish corrective actions.
11. Establish verification procedures.
12. Establish documentation and record keeping.

For processing, quality checks require even more concern, such as the amount of sulphur used, the period of exposure and the size of pieces treated, sugar concentration, salt concentration, temperature of heating, etc.

Preparation of raw material and ingredients mixing for processing, preparation of products by peeling, slicing, pulping and filtering must be controlled. The objectives of verification of each operation is to ensure that products are peeled correctly, sliced to even size slices and that pulping followed by filtering is done properly with clean material.

Mixing ingredients to prepare a batch for processing is a very important operation. Any mistake made in determining the amount and required combination ratio, will affect considerably the quality of the final product. For that reason each batch number is kept in a record book and the amount of ingredients used is also ticked off as they are added to each solution or mixture. If the scale is not available, the use of calibrated cups and spoons is accepted if the same amount is used. For syrup and brine solutions, the concentration of sugar and salt should be checked for each batch.

Quality assurance and good manufacturing management require a good quality of records related to raw materials (variety, harvest time, inspection, sorting and preparation of the product) and to processing technique from batch preparation (amount, type, source of the ingredients used), method of processing applied (temperature, concentration, duration etc.), packaging, packing and labeling. Information is essential to trace any defect of production and handling.

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# MODIFIED AND CONTROLLED ATMOSPHERES

The technology of modified and controlled atmosphere is widely used for the storage, transport, and packaging of several types of foods. Modified atmosphere (MA) refers to any atmosphere that is different than the normal air (20.95%) $O_2$, about 0.03% $CO_2$, about 78.08% $N_2$, and trace quantities of other gases), while controlled atmosphere (CA) refers to atmospheres different than normal air and strictly controlled during all the time. MA and CA usually involve an atmosphere with reduced concentration of $O_2$ and/or an elevated concentration of $CO_2$. Hypobaric (low pressure) storage is a MA or CA system involving the use of vacuum to reduce the partial pressure of the gas component of air.

Optimum atmosphere for different types of foods is very variable, and depends on many factors such as type of product, purpose of use, physiological age, temperature, and duration of treatment. Exposure of horticultural products to $O_2$ levels below, and/or $CO_2$ levels above their optimum tolerable range can cause the initiation and/or aggravation of certain physiological disorders, irregular ripening, increased susceptibility to decay, development of off-flavors, and could eventually cause the loss of the product. Most horticultural crops can tolerate extreme levels of gases when stored for only short periods.

In the last 2 decades there have been major changes in food consumption habits. There has been a major shift and a significant increase in the consumption of fresh fruits and vegetables, mainly due to health concerns. These changes have created the needs for the development of adequate technologies to preserve these perishable food items. MA and CA have been used for storage and transport of foods for at least the last 7 decades. Today more than 15 million tons of apples are stored in CA in different regions of the world. The 1980`s have shown major improvement in the technology and a significant increase in uses in storage, transport, and packaging of different types of foods.

**Advantages of using MA and CA storage include:**

- Retardation of metabolic processes, such as ripening and senescence in fruits and vegetables, and rancidity in different types of foods such as nuts, potato chips, etc.
- Retardation of the loss of some nutritional substances such as vitamins.
- Decay control.
- Insect control.
- Control or alleviation of some physiological disorders such as chilling injury in some fruits and vegetables.
- MA and CA should always be used as a supplement and never as a substitute for proper handling techniques, especially optimum temperature and relative humidity.

**Some of the very important improvements in the technology in the last 2-3 decades include:**

- Improvements in the structural techniques for development of hermetic rooms and transport containers.
- Technology of nitrogen separation.
- Improvements in the development and use of gas control and analysis.
- Improvements in the development and use of modified atmosphere packaging systems.

Figure 1. View of CA storage rooms.

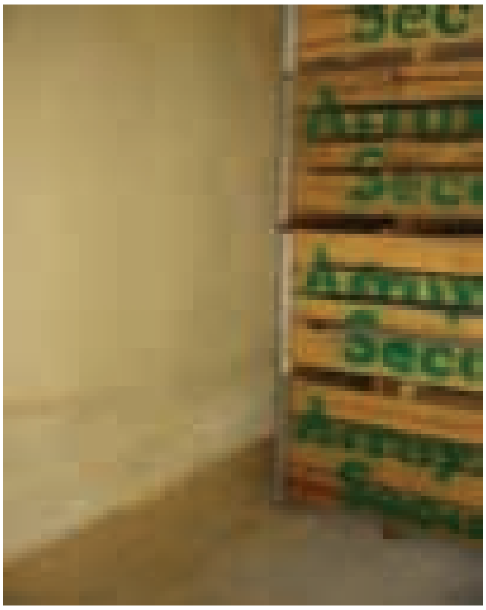


Figure 2. The interior of a CA room (Dr. Elhadi Yahia)

Figure 3. Nitrogen separator from air used in CA storage (Dr. Elhadi Yahia).

CA storage has been restricted mainly to apples, pears, kiwi fruit and cabbage. MA and CA are used to transport almost all fruits and vegetables, among other types of foods. Packaging in MA is used for several types of foods, including minimally processed fruits and vegetables.

Some of the potential hazards and harmful effects of MA and CA, when used improperly, include:

- Initiation or aggravation of some physiological disorders, irregular ripening, and increased susceptibility to decay in fruits and vegetables.
- Fermentation and production of off flavors in different types of foods.
- Potential development of anaerobic bacteria, especially when temperature is higher than optimum.
- Structural deterioration in storage rooms and transport containers that lack proper pressure relief systems.

**Storage in CA**

**Apples**. Apple storage in CA is widely used in almost all apple growing regions in the world. The technology was developed since about 6 decades ago for the storage of this fruit. Currently several millions of tons of apples are maintained for prolonged periods of time in CA. For example, in the USA about 1.5 million tons of apples are stored in CA annually. The latest recommendations indicate the advantages of using $O_2$ concentrations at or below 2%. These concentrations provide better quality retention, reduce the incidence of some physiological disorders such as scald, and extend storage life. Automated control is very essential when $O_2$ concentration is at or below 1%, to avoid the possibility of anaerobic fermentation. The use of lower $O_2$ concentrations of $O_2$ should be combined with lower concentrations of $CO_2$ to avoid injury, especially in sensitive cultivars. CA storage, especially lower concentrations of $O_2$ (< 1.5%) and control of harvest maturity is sought to be as an alternative to diphenylamine and ethoxyquin scald treatments. Table 1 indicates optimum conditions for some apple cultivars.

**Table 1.** Optimum CA storage conditions and recommendations for some apple cultivars.

| Cultivar | Temp. ºC | %$O_2$ | %$CO_2$ | Months | Comments |
|---|---|---|---|---|---|
| Golden Delicious | -01-2 | 1-2.5 | 1.5-4 | 8-10 | Tolerant to $CO_2$ |
| Red Delicious | -0.5-1.0 | 1-2.5 | 1-3 | 8-10 | Very susceptible to scald, high $CO_2$, low $O_2$ cause fermentation |
| Fuji | 0-2 | 1-2.5 | 0.7-2 | 7-8 | Develops scald, fermented by high $CO_2$/low $O_2$ |
| Gala | -0.5-3 | 1-2.5 | 1-5 | 5-6 | Rapid CA recommended |
| Granny Smith | -0.5-2 | 0.8-2.5 | 0.8-5.0 | 8-10 | Very susceptible to scald, high $CO_2$ cause internal browning |
| Jonagold | 0-2 | 1-3 | 1-3 | 5-7 | Can develop scald |

**Pears**. Storage of pears in CA is widely practiced in different countries. The use of very low concentrations of $O_2$ (< 3%) is recommended. This should be combined with very low concentrations of $CO_2$ to prevent brown core. CA is helpful in control of superficial scald ($\leq$ 1% $O_2$).

**Table 2.** Optimum CA storage conditions and recommendations for some pear cultivars.

| Cultivar | Temp. ºC | % $O_2$ | % $CO_2$ | Months | Comments |
|---|---|---|---|---|---|
| Anjou | -1-0 | 0.5-2 | < 0.5-2 | 5-8 | Susceptible to scald |
| Bartlett | -1-2 | 1-3 | 0.5-3 | 3-6 | > 0.5% $CO_2$/1% $O_2$ cause core browning |
| Bosc | -1-0 | 0.5-2 | 0-1.5 | 4-6 | |
| Comice | -1-0 | 0.5-3 | < 1-3 | 5-6 | |
| Conference | -1-0 | 1.5-3 | < 1-3 | 6-8 | |

**Kiwi fruit**. Storage of kiwi fruit in CA is practiced in several countries and its use is expanding. Optimum conditions are 1-2% $O_2$, 3-5% $CO_2$ at 0-5ºC. It is recommended that CA is established within 2 days after harvest at the latest, and ethylene concentration must be maintained below 20 ppb to delay flesh softening and prevent incidence of white core inclusions. CA advantages include delayed senescence and firmness retention. $O_2$ concentrations below 1% and $CO_2$ concentrations above 7% cause injuries in the form of off-flavors and internal breakdown of the flesh.

**Cabbage**. Cabbage is the only vegetable currently stored in CA prior to processing. Optimum $O_2$ (2-3%) and $CO_2$ (3-6%) concentrations vary depending on cultivar and storage conditions. CA advantages for cabbage include reduced color changes, trimming loss, sprouting, and decay.

**Prospects for other fruits**

Excellent perspectives exist for the prolonged CA storage of other fruits such as avocados and bananas.

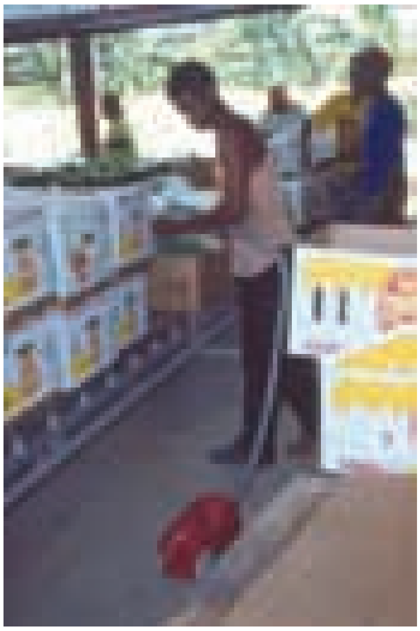
**Transport in MA/CA**

Transport of meat in MA started about 7 decades ago, and that of fruits and vegetables since about 3-4 decades ago. The use of MA/CA can encourage the use of sea transport, since it is cheaper than air transport. Atmospheres for transport can be developed passively, semi-actively, or actively. Passive systems are MA regimes where the atmosphere is modified by fruit respiration and the permeability of a barrier material. In the semi-active systems, one or more gases is/are added or withdrawn, most commonly at the beginning, but no strict control is carried out. Active systems imply a strict control of the atmosphere during all transport period. The most common systems for transport in the last 30 years have been developed on a semi-active basis, and used for transport of bananas and strawberries, though usually less efficient, they are less expensive than active systems.

A CA container has the same features as that of a refrigerated container, in addition to a higher level of gas tightness, $O_2$ and $CO_2$ control systems, and perhaps systems for control of ethylene and relative humidity (RH). CA systems for transport should be used when transport periods are long and/or food is very perishable.

Important developments in the transport of foods in MA/CA have been accomplished in the last 15 years. Among those are the development of better sealed containers, air separation techniques, better gas monitoring and control systems. Due to these developments a major increase in products, especially fruits and vegetables, are transported in CA by sea.

The following pictures indicate a strawberry pallet being treated with modified atmosphere (from Dr. A.A. Kader, UC Davis), a marine transport container being prepared for MA application (Dr. E.M. Yahia), melons being packaged in MA, and modified atmosphere being applied to a banana box (Dr. E.M. Yahia).



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# PACKING

Packing refers to the set of handling practices carried out to prepare the commodity for packaging and marketing. It includes several treatments and practices such as cleaning, washing, curing, sorting, sizing, waxing, fungicide treatments, packaging, palleting, etc.

Packing can be done in the field or in "packing sheds" or "packinghouses" with different designs, depending on the type of commodity, the intended market and type of investment. There is no standard "packing" facility, and packinghouses can vary from a very simple shed to a very big and sophisticated equipped packing place. However, several basic requirements should always be available. The site should protect the crop from heating and physical injury, and preferably should provide workers with a comfortable working environment. The packing site should be located where there is accessibility to roads and markets, and other needed services.

Figure 1. Trimming grapes during packing (Dr. Rawia Basiouni).

**Field packing**

Field packing is commonly practiced for several crops such as lettuce, strawberries, green onions, celery, and grapes, among others. This type of packing, which is done either right at the site of the plant (as is the case for lettuce and strawberries) or at the end of the line or orchard as in the case of grapes, is very popular due to several advantages. It significantly reduces handling damages during transport and all other further postharvest chain processes. During this packing system, the crop is commonly selected, sized, trimmed, and packaged in shipping containers or even in consumer packages (as in the case of strawberries). This shipping system also reduces initial investment compared to packing in an established packinghouse. There is a tendency to increase the use of field packing.

However, field packing has some disadvantages such as difficulties for managing quality control, and for providing a comfortable work environment for labors. In addition, there are some postharvest practices and treatments that can not be implemented in this system such as waxing, quarantine systems, etc.

**Location of the packing facility**

The selection of the site of the packing facility is essential. Several important factors should be considered, including:

- **Proximity to production area**. This is important to reduce transport distance and therefore to reduce the deterioration of the product.

- **Availability of labors**. There is usually a strong need for labors during the packing season.

- **Availability of services and technical assistance**. Packinghouses (depending on how sophisticated they are) will always need adequate maintenance and servicing.

**A packing site should include the following components**:

**Receiving area**. This should be shaded to protect the product from heat. In this area the product may wait for some time before being loaded on the packing line. In this area the product is commonly weighed and a sample should be taken to evaluate initial quality.

**Packing line**. This can include several treatments such as cleaning (removing of debris), washing, sorting, drying, sizing, quality grading, waxing, fungicide application, packaging, palletizing, etc.

**Dispatching area**. This area can include practices such as quality inspection facilities for final product, palletizing, pre-cooling, storage and ripening rooms, and loading on transport vehicles.

**Practices and processes done in a packinghouse**

**Cleaning and/or washing**. Fresh horticultural crops can be received in the packing line or in water tank to reduce the mechanical damage. Crops that can withstand water are recommended to be received in wet (e.g carrots, potatoes, banana, etc). Water can clean and cool the crop, and in addition it can be used as a vehicle for chemical applications.

**Sorting.** Crops are commonly sorted to eliminate those that are not fit for packing such as those that are undersized, oversized, deformed, deteriorated, immature, over mature, etc.

**Drying**. This is usually done to remove the water from the surface of the product, especially important when waxing is intended to be carried out.

**Grading**. The product is then classified to different quality grades according to size, shape, color, ripening stages, freedom from defects, etc.

**Sizing**. This can be done before or after grading, either manually or mechanically depending of the product and the intended market. Sizing can be done on the bases of dimensions or weight.

**Waxing**. Waxing is done to reduce water loss and to increase gloss, and attractiveness of the quality of the product. Several waxing formulas are available and used, but it is recommended that natural (rather than synthetic) waxes be used. Drying after waxing is essential. Waxes are sometimes mixed with fungicides such as TB2.

**Packing**. Packing can be done in several types of shipping or consumer packages depending on the type of crop. This is commonly done manually to reduce mechanical injury, although some mechanical packaging is some time implemented.

**Palletizing**. This is usually done manually. Pallets are standardized for the main markets (European or USA).

**Management of the packing facility**

The packing shed or packinghouse, whether it is simple or sophisticated, needs to be managed adequately. Several important factors are essential:

- Cleanness / hygiene.
- Organization.
- Data control.
- Maintenance.

Figure 2. Mango packinghouse in Mexico (Dr. Elhadi Yahia).


Figure 3. Packing of apples in carton boxes (Dr. Elhadi Yahia).


Figure 4. Packing of dates in carton boxes (Dr. Elhadi Yahia)

Figure 5. Packing of  bananas in carton boxes.

Figure 6. Packing potatoes in carton boxes.

Figure7. Stacking grapes packages (Dr. Rawia Basiouni).

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# PACKAGING

Packages and packaging systems are very important components of the postharvest handling chain of fresh horticultural crops. Packages are made of different sizes, shapes and materials depending on the type of product, and the purpose of their use. Packages and the process of packaging should meet several objectives, which include:

**Contain the produce**. The package should act as a container for the product in order to create an efficient handling unit, easily handled by a person, and easily maintained during transport, storage, and marketing. Many packages in developing countries do not fit this specification, as they are too big and therefore they harm the produce and make it very difficult to be handled.

**Protect the produce**. Fresh horticultural crops are prone to mechanical injury in several ways such as:

1. Compression bruising. This type of injury is commonly resulted from the overfilling of the package, improper stacking, deterioration of the package, or due to pressing of the produce by upper layers. It can be avoided by packaging in containers strong enough to withstand multiple stacking and not to overfill the package. Packages in developing countries are commonly overfilled, which results in excessive injury and losses. Packages should always be full but never overfilled.
2. Impact damage. This is mostly caused by dropping or throwing the package (due to big sizes and excessive weight), and by shocks during transport caused by excessive braking, and by fast driving and movements of the produce, and also due to inadequate conditions of roads. This problem is common in developing countries due to excessive weight of package, inadequate conditions of vehicles, and driving, and poor conditions of roads. This damage can be avoided by using small packages that can be easily handled by one person, and by training drivers to handle these crops carefully, to drive carefully, and to use better roads.
3. Vibration rubbing. This damage is resulted from vibration of the loose product in the package or between each other, which can cause abrasions. This can be avoided by packing the product tightly (but not overfilled). Several other means can also be implemented to reduce this problem including the use of different types of liners, and wrapping of the produce in paper or other materials.
4. Cut and punctures. These are common when hard packages are used, such as wood crates and some baskets.

**Communicate the product**. The package should be labeled to indicate sufficient information on the product. Labels should include the following:

1. Description of content (product type, variety, size class, quality grade).
2. Net weight or count.
3. Country of origin.
4. Name and address of grower, packer or exporter (responsibility statement).
5. Brand name, if any.

6. Some markets require the description of some treatments such as the use of pesticides, waxes, heat treatments, etc.

**Promote and sell the product**. Packages are the most effective and most inexpensive system for promotion, and therefore, the package should be designed to be also attractive.
**Better use of space during transport or storage**. Big baskets used in some developing countries for fresh fruits and vegetables are inadequate and are inefficient for the use of space during transport and storage.
**Facilitate cooling**. The package should contain sufficient ventilation openings that are located at the right side(s), depending on the type of air circulation.

**Different levels of packaging:**

**Harvesting packages**. These are packages that are used to collect the product from the field such as cloth bags for oranges harvesting and plastic packages.

**Field packages**. These packages are used to accumulate the harvested product in the field before transporting it to the packinghouse or the pre-cooling site. These packages are commonly made of wood (range in capacity between 10 to 400 kg), or plastic boxes (ranging in capacity between (14 to 20 kg).

**Shipping packages**. These are different packages used during shipping, but also can be used during storage and marketing. They can be made of wood, plastic, fiberboard, etc. The capacity of these packages ranges between 3 to 18 kg.

**Consumer packages**. These packages are increasingly used for direct marketing to consumers, and they are made of different materials such as different types of plastics, paper, and fiberboard carton. They have several advantages including reduced damage and handling of the produce, increased marketing and profits, and more convenience to the consumer.

**Difficulties of packaging fresh horticultural crops**:
Fresh horticultural crops are difficult to package due to several reasons:
- Live organs: fragile, deteriorate constantly.
- Absorb gases (such as $O_2$), and release other gases (such as $CO_2$ and $C_2H_4$), and produce heat.
- Loose water (transpiration).
- Easily infected by microorganisms and insects.

**Types of packages and materials**
**Sacks and nets**. These are used in various materials, sizes and forms for several less perishable crops. For example sacks with a different capacities, up to 85 Kg, are commonly used for potatoes all over the world. Other crops where sacks are used include onions, chilies, carrots, yams, among other less perishable crops. Materials used to make sacks include woven natural fibers, but most commonly nowadays polyethylene and polypropylene.

Sacks are commonly used because of their low prices, availability, easy handling, commonly used multiple times, and occupy a small space to be shipped for re-use. However, sacks as packages have several disadvantages. Sacks are not commonly washed or cleaned when used several times, and therefore they can be a source of decay organisms. Sacks do not provide a good protection for fresh horticultural crops, especially the perishable ones. Mechanical injuries caused by sacks as packages, especially compression damage, are very common. Most commonly used sacks are too large to be handled by one person. For example sacks used for potatoes in some developing countries are of 85 Kg, which are much beyond the handling capacity of one person.

**Baskets**. Baskets are commonly used in developing countries. Traditional round wicker type baskets have several sizes and capacities from about 3 kg to more than 70 kg, and are made from different materials such as bamboo, jute, willow, or straw. Baskets are usually cheap, and materials are commonly available locally. However, they have several disadvantages in relation to the handling of fresh horticultural crops. Their sizes are usually big which makes them extremely difficult to be handled by one person, and promotes losses of the product. In addition, their round shape makes the use of space in storage and transport systems very difficult and extremely inefficient. Injuries and losses of fresh horticultural crops packaged in baskets are the highest among all other types of packages. This is especially obvious during transport and piling of baskets on top of each other.

**Wooden crates**. Wooden crates of different sizes and forms are widely used for the packaging of horticultural crops. Most field boxes for apples and many shipping containers for several crops are made of wood. These have several advantages including their excellent stacking force, and excellent protection from compression damage, resistance to weather conditions including water, and can be re-used. However, the rough surface of wooden boxes can cause injuries such as cuts and abrasions when they are not made adequately, and non treated wood becomes easily contaminated with decay. Wooden boxes are not easily labeled, and therefore crops packaged in wooden crates are not well promoted. Liners can be used to reduce injuries caused by these packages. Wooden crates and boxes also present an environmental problem (deforestation).

**Fiberboard (corrugated cardboard) cartons**. These are increasingly used for packaging of fresh horticultural crops. There are practically no standard sizes or shapes in the world markets, although several intents have been made to develop such standards. They can be of solid or corrugated fiberboard, and with different thickness and stacking force. Fiberboard cartons have several advantages. They are light in weight, have smooth surface and therefore they do not cause excessive injuries, can be easily manufactured in different sizes, shapes, and strength, and can be easily labeled in different colors making them very attractive. In addition, these packages are biodegradable. However, fiberboard boxes can easily absorb water which can decrease their strength, unless they are waxed. Stacking force can be improved by using adequate materials and thickness, waxing of the material, the use of internal separators, or by using half or full telescopic boxes. Fiberboard boxes are the common packages used for the export market.

**Plastic crates**. Plastic crates are made in different sizes and shapes. They are commonly used as field containers, having a capacity of 14-20 kg. Plastic crates have advantages over wooden crates in that they have a smoother surface, and can be cleaned much easier. Lately some designs are available for re-usable plastic containers.

**Plastic films and bags**. The use of plastic films and bags for the packaging of fresh horticultural crops is increasing all over the world. Plastic types used are variable such as polyethylene (low and high density), polypropylene, polystyrene, etc. These packages are made in different shapes and sizes and colors depending on the type of crops and the purpose of use. Plastic films and bags have differential permeabilities for gases and water vapor, and therefore they can serve to reduce water loss and may provide a modified atmosphere around the packaged crop. However, care should be taken to select the appropriate film (appropriate permeability) in order to avoid the condensation of water inside the package, and/or the creation of an anaerobic atmosphere. Plastic materials are also been used as liners inside the packages.

**Paper bags**. The use of paper bags has decreased lately as packages, but they are still been used as liners and dividers to reduce produce rubbing. Some colorful paper tissues are some times used to make the crop more attractive, or may even contain a fungicide to prevent against certain decay organisms.

**Choosing the right package**

The right package should be chosen on the basis of:

**Type and perishability of the product**. The package should protect the product and not causing injury to it.

**Type of market**. Different markets require specific packages. The package should never detract from the quality of the product, but rather it should add to it. Packages usually add to the cost, but that can be done in a way which can increase profitability.

**Safety measures**. The packages should not contaminate the product, and therefore it is recommended to use packages that were not meant for perishable foods.

**Size and weight**. The package should be handled easily by one person, and never beyond his capacity.

**Facilitate cooling**. The used package should facilitate the cooling of the product, and never causes its heating. Facilitate the ventilation for exchange the gases.

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# TRANSPORT

Food marketing and consumption centers are commonly far from production areas of horticultural crops. In addition, the accessibility to world markets, including distant ones, has increased in the last few years. These factors emphasize the need for improved transport methods and infrastructure.

Proper transport management is extremely essential in modern horticulture. Good transport requires effective packing, packaging, palletization, stacking, proper temperature and air circulation and ventilation. One of the major causes of produce deterioration and losses is mechanical damage, and thus transport should avoid this problem.

Several technologies have been developed to improve the handling of fresh horticultural crops during transport. Some of these technologies include the use of modified and controlled atmospheres, ripening, quarantine systems, etc, aboard transport vehicles, especially during marine transport.

In the last years rail transport of horticultural crops has declined, while road and marine transport have increased in the world.

**Mode of transport**

The mode of transportation of fresh horticultural crops depends on distance, perishability and value of the product, and cost of transportation method. Different modes of transport used for horticultural crops in the world, include:

- Road transport (trucks, refrigerated or not)
- Railroad transport
- Water transport (rivers, lakes, canals, sea)
- Air transport (cargo or passenger)

In all types of transport methods, several factors should be observed, including:

- Produce should be protected from heating, wind, water loss, and mechanical injury.
- Loading and unloading should be executed fast and careful.
- Loading tightly to reduce movement and make best use of space.
- Distribute weight evenly.
- Provide sufficient spaces for ventilation and air circulation.
- Do not exceed the capacity of the vehicle or container.

**Road transport**

This transport system has increased very significantly all over the world, and now is the most dominant transport system due to several reasons, such as:

1. Flexibility, door to door delivery, fast, easy loading and unloading.
2. Roads improvements.
3. Development of compact portable refrigeration systems.

However, this transport system can be energy intensive, expensive, and need a relatively developed road infrastructure.

In many developing countries, land transport is done with open non-refrigerated trucks. These are sometimes managed inadequately. The produce is loaded in ways which promotes major problems such as, inadequate transport containers, inappropriate stacking, inadequate packages, very rough loading methods, poor or non existing air circulation, heating and mechanical injury to the produce. This system must be changed, if food losses are to be reduced. Non-refrigerated transport must be improved by reducing the transported load, improving the stacking system, avoid heating and mechanical damage to the produce. Refrigerated containers should be increased.

Enclosed vehicles are suitable for short journey, and often used for urban retail delivery. Open pick-ups and open trucks are common for road transport in developing countries. Natural ventilation is always sufficient to prevent heating during short distance transport; however, for long distance transport this may not be adequate, and thus refrigerated vehicles become necessary.

There is a tendency, especially in some developing countries, to use refrigerated containers for pre-cooling of produce, which is not very effective due to insufficient refrigeration capacity Fig (1). In other cases, in some developing countries, refrigerated containers are used as permanent storage space especially in wholesale markets, which is also not very effective, especially if the refrigerated container is old and deteriorated.

Figure 1. Refrigerated transport vehicle (Dr. Elhadi Yahia).

**Railroad transport**

This transport system can provide smooth ride, relatively inexpensive, even though it is slower than other transport systems (mainly road transport), and less versatile. However, this system of transport is declining significantly all over the world, although the increasing cost of fuel may revive interests for its use.

**River transport**

River transport is commonly used in several countries especially in Asia. This system can be slow, and it is commonly non-refrigerated.

**Sea transport**

Sea transport of horticultural crops has increased very significantly all over the world. This is due to the significant increase in horticultural crop trade, and its low cost compared to air transport Fig (2a, 2b).

This transport system is usually used for long distances, and therefore it is not adequate for very perishable crops.

Reefer vessels are mostly refrigerated, with adequate air circulation system, and controllable rates of air-exchange. Capacity of reefer vessels is usually high (2000-4000 tons or more).
Reefer or intermodal containers are specialized form of sea transportation and their use is increasing in world trade of fresh horticultural crops. These are of standard size of 8 (wide) x 8.5 (high) feet cross section, and 10, 20, 30, or 40 feet long. The most commonly used containers are those of 20 and 40 feet. Refrigeration of the container is either independent powered electrically by the container vessel (integral containers), or provided entirely by vessel system (porthole containers). Most of containers for fresh fruits and vegetables are constructed with bottom (vertical) air delivery. Reefer containers have several advantages such as they can be loaded at the packinghouse, reduction in handling losses, independent temperature control, and possibility for the use of modified and controlled atmospheres. However, they can be expensive, unavailability of handling facilities for containers in some ports, require special lifting equipments, possibility for damages, and delayed returns of the containers.

Figure 3. View of a sea port showing handling of containers (Dr. Elhadi Yahia).

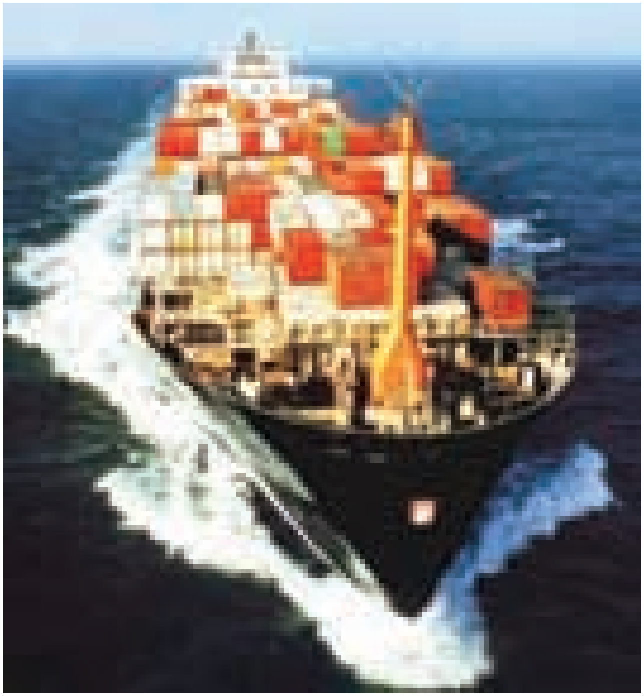

Figure 2. Marine transport.

**Air transport**
Air transport is still mostly done on passenger airplanes with very little quantities of fresh horticultural crops been carried on cargo planes. This system is relatively fast and therefore it is suitable for very perishable crops (such as berries and flowers) and that of high value; however its cost is still very high.

Equipments available for this system include air cargo containers, and air cargo pallets with netting.

Many crops transported by air from several developing countries are not pre-cooled, nor refrigerated before shipping, and airports and planes do not provide refrigeration system. Most of the packages used for these crops are inadequate, and most of them are not even meant for perishable crops.

Due to the high cost of air transport, produce shipped should be of the highest quality, and quality deterioration should be reduced before, during and after transport.

The produce should be pre-cooled, and maintained at the lowest possible temperature (close to optimum temperature), and should arrive to the airport well ahead of the flight departure. Facilities should be available at the airport to keep the produce during the waiting period in a protected environment and at the proper temperature. At the waiting points the produce should be handled with care to avoid heating, and mechanical damage. Logistic and paper work at the airport should be done in advance.

Air shipments of fresh produce are still mostly done with passenger carriers. Passenger and cargo carriers usually use unit load containers (Fig 3), but also can carry packages loaded as loose bulk.

In addition to the lack of refrigeration, especially on passenger planes, produce heating can be a major problem during waiting periods and over stops at airports.

Produce shipped in passenger carriers is usually maintained at the same temperature and pressure as the passenger cabin. However, lower temperatures can be maintained by the use of gel refrigerants or dry ice (solid $CO_2$). In addition to decreasing the temperature of the produce, dry ice can increase the concentration of $CO_2$ in the atmosphere, and may provide a slightly modified atmosphere. Insulation materials could be used around the containers to prevent temperature increase of produce in the container.

Figure 4. Container used for air transport (Dr. Elhadi Yahia).

Figure 5. Use of insulation material around the container to prevent heating of produces (Dr. Elhadi Yahia).

**Management of horticultural crops during transport**

Transport system should protect the produce from deterioration by high temperature, high air movements, low relative humidity (increases water loss), mechanical damage, and should not cause any safety problems.

Fresh produce losses in developing countries due to transport are very high, mainly due to overheating and mechanical injury. Refrigerated transport is not commonly used, and roads and vehicles conditions are not usually adequate. In addition, packages used during transport have several disadvantages including inadequate use of space (such as the case of baskets), big size, and increased mechanical damage to produce.

Although refrigeration is very important during the transport of fresh horticultural crops, non-refrigerated transport systems can be used, especially for short distances and for products that are not very perishable. Non-refrigerated transport vehicles should be adequately covered to be protected from rain, high temperatures, and air movements. It is preferable that non-refrigerated transport be carried out when temperature is low (night, early morning, late afternoons). Loading and arrangement of the produce in these non-refrigerated vehicles should be done in a manner that will not cause the warming-up of the crop. The vehicle should not be overloaded, and the load should be adequately fixed. Truck suspension system should be always checked and maintained in an adequate condition, and driver should avoid the use of poor roads, and should be trained to drive adequately to reduce load movement and mechanical injury. The vehicle should be maintained clean, especially in the interior.

The use of refrigerated transport is increasing in many countries, especially during road and marine transport. Refrigerated vehicles/containers should be managed adequately to reduce quality deterioration, and to preserve produce quality. The following factors should be observed very carefully:

- Refrigerated capacity of the container should be adequate.
- The vehicle and the load should be pre-cooled before loading.
- Good air circulation is required to maintain temperature uniformity, to avoid the build-up of hot spots, and the accumulation of gases such as $CO_2$ and ethylene.
- Transport containers should not be overloaded to permit an adequate air circulation.
- Stacking patterns, and packages type and designs should be adequate to permit an adequate air movement. Package design should take in consideration the type of air circulation in the transport container. Sufficient spaces should be allowed in top, bottom, back and sides of the load to permit air circulation.
- A ventilation system should be adequate to eliminate the accumulation of gases such as $CO_2$ and ethylene and other undesirable volatiles and odors.
- The load should remain stable during the entire transit. Load movement should be prevented by using braces, bars, gates or other devices.
- Transport container should be kept clean.
- Light external container colors can reduce heating of the load (reflects heat), instead of dark colored external color containers which can heat the load (by absorbing heat).
- Care should be taken to reduce damage to container walls, and thus avoiding damaging the insulation system.

Figure 6. Refrigerated transport unit (Dr. Rawia Basiouni).

**Temperature control**

Temperature control and devices are important in refrigerated containers. Thermostats should control the cooling and heating systems, the defrost mechanism, and the fans. It is preferable that temperature monitoring devices (Fig 7), be placed in return-air and the discharge-air channels. If only one monitoring device is to be used, it is important to be located in the return-air (warm position) channels. However, the most important temperature to be monitored is that of the produce itself. Thermostats used should be accurately calibrated periodically.

For refrigerated containers/vehicles refrigerated units are commonly mounted directly on the container, and powered by diesel motors, or by electricity on docks or on ships in the case of marine transport.

Crushed ice is sometimes used as a supplement to refrigeration either on top of the load, or in containers, especially during road transport of some crops.

Figure 7. Internal view of a refrigerated vehicle/container showing stacking and bracing

Figure 8. Rayan's temperature recorder used to monitor temperature changes in shipments (Dr. E. Yahia)

**Air circulation**

Adequate air circulation is very important to maintain a uniform temperature, to avoid the build-up of heated spots, and also to avoid the build-up of gases and volatiles. Two types of air circulation are commonly used:

- Top (horizontal) air delivery. This type is common in road transport vehicles, where cold air is blown by a fan over the top of the load (Fig 8 a).
- Bottom (vertical) air delivery. This type is common in marine containers, where cold air is blown vertically from the bottom of the load. This system provides a better air circulation resulting in a better temperature control. (Fig 8 b).

Fig (8) mechanism of cooling

Figure 8. Mechanism of cooling: a) Top air delivery, b) Bottom-Air delivery (U.C. Davis).

**Product compatibility in mixed loads**

Fresh horticultural crops are commonly transported as "mixed loads", however, only compatible products should be transported together. Grouping of non-compatible products may result in deterioration and losses. Compatibility is decided on the bases of different factors, such as:

- **Temperature**. Different crops require different temperatures. For example, lettuce and strawberry need to be transported at 0ºC, summer squash, peppers at 10ºC, and banana at 13-15ºC. If compromise is to be made for holding several commodities together, it is important to protect the most perishable or most valuable product.
- **Relative humidity**. Crops that need to be maintained at very high relative humidity (such as lettuce at 95-98%) should not be maintained with crops that need to be maintained at lower relative humidity (such as fruits at 80-85% or dry onions and garlic at 65-70%).
- **Ethylene**. Crops that produce large quantities of ethylene (such as apples, pears and several other climacteric fruits) should not be maintained with crops that are sensitive to ethylene (such as kiwifruit, cucumbers, leafy vegetables, cut flowers).
- **Modified/controlled atmospheres**. Different fruits, and even different cultivars of the same fruit, have specific and different $CO_2$ and $O_2$ requirements when transported in MA and CA.
- **Odor**. Products that produce odors (such as onions and garlic) should not be mixed with other products that can absorb such odors (such as apples).

- **Other factors**. $SO_2$ which is commonly used for grapes to inhibit the development of decay organisms can cause injury to almost all other fresh horticultural crops, and therefore treated grapes should not be mixed with other crops.

**Modified (MA)/controlled atmospheres (CA)**
MA and CA are increasingly been used in marine transport containers for several fruits and vegetables. Several MA and CA systems are available, which operate differently. It is essential that adequate atmospheres be used for each crop. Containers should be gas tight, and atmosphere be controlled automatically. Details on MA and CA are provided in a specific section of this manual.

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# PHYSIOLOGICAL DISORDERS

Physiological disorders are those that are not caused by any fungal, bacterial, viral or insect agent. Physiological disorders can occur before or after harvest. Several physiological disorders are initiated before harvest and commonly appeared after harvest, especially during storage. The causes of these disorders are diverse and include temperature (low or high), mineral imbalance, chemicals including ethylene, wind, hail, and some agricultural practices.

**Freezing injury**. Temperature below freezing point, either before or after harvest, can cause freezing injury which causes the collapsing of the tissue. Freezing injury causes degradation of tissue structure and losses of several components including vitamins. Freezing injury occur at below 0ºC, depending on the soluble solids content of the tissue. Products with higher soluble solids content will freeze at a lower temperature. The range of temperatures at which some fruits and vegetables freeze are –2.2 to –1.7ºC (1.8 to –1.7ºC in potatoes -0.9 to –0.8ºC in cucumber and 0.6 to -0.3ºC in lettuce).

**Chilling injury**. Chilling injury (CI) is different than freezing injury in that it occurs above freezing temperatures, at a range of temperatures of 0ºC to 14ºC. CI disorders and symptoms include collapse and necrosis of tissue, pitting, water soaking, loss of flavor and aroma, increased susceptibility to decay and finally the death of tissue. CI is cumulative has a great economic importance because chilling sensitive crops can not be maintained at low temperature, and therefore they are usually stored for a short period and their quantitative losses are high, compared to non-sensitive commodities. Many subtropical and tropical crops are chilling sensitive. CI is cumulative and usually appears after about 2 days at room temperature following low temperature storage.

Several causes have been suggested for CI; among the most important is a phase transition of membrane lipids from liquid to a crystalline state. This phase change modifies the activation energy of lipid-associated respiratory enzymes. Several factors affect CI including maturity (ripe fruits are less sensitive), atmosphere modification (high concentrations of $CO_2$ ameliorate CI), high temperatures (reduce CI incidence), calcium applications (reduce symptoms).

CI injury is prevented with the use of optimum (above critical) temperatures, and can be ameliorated with intermittent warming, high $CO_2$ atmospheres (if tolerated by the tissue), heat treatments, and calcium applications.

Figure 1. Chilling injury symptoms on melons (Dr. A.A. Kader).

Figure 2. Freezing injury in potato (Dr. A.A. Kader).

**Table 1.** Examples of crops insensitive to chilling injury and their optimum holding temperatures.

| Crop | Temperature (°C) |
|---|---|
| **Vegetables:** | |
| Beet | 0 |
| Broccoli | 0 |
| Carrots | 0 |
| Celery | 0 |
| Garlic | 0 |
| Globe artichoke | 0 |
| Lettuce | 0 |
| Onions | 0 |
| Parsley | 0 |
| Radish | 0 |
| Spinach | 0 |
| Sweet corn | 0 |
| **Fruits:** | |
| Apricot | -0.5 – 0 |
| Blueberries | -0.5 – 0 |
| Cashew apple | 0-2 |
| Fresh figs | -0.5 – 0 |
| Grapes | -0.5 – 0 |
| Kiwifruit | 0 |
| Loquat | 0 |
| Peach | -0.5 – 0 |
| Pear (American) | -1.5 – 0.5 |
| Pear (Asian) | 1 |
| Plums and prunes | -0.5 – 0 |
| Sweet, sour Cherries | 0 |
| Strawberries | 0 |


Figure 3. Chilling injury in tomato (Dr. A.A. Kader).

**Table 2.** Examples of chilling sensitive crops and their optimum holding temperatures.

| Crop | Temperature (°C) |
|---|---|
| **Vegetables**: | |
| Bell pepper | 7-10 |
| Cucumber | 10-12 |
| Eggplant | 8-12 |
| Ginger | 13 |
| Hot peppers | 5-10 |
| Melon, casaba | 7-10 |
| Melon, Crenshaw | 7-10 |
| Melon, Honeydew | 5-10 |
| Okra | 7-10 |
| Summer squash | 7-10 |
| Tomato | 7-13 |
| Sweet potato, yam | 13-15 |
| Winter squash | 12-15 |
| Water melon | 10-15 |
| **Fruits**: | |
| Avocado (Hass) | 3-7 |
| Bananas | 13-15 |
| Cherimoya, custard apples | 13 |
| Grapefruit | 10-15 |
| Guava | 5-10 |
| Jackfruit | 13 |
| Lemon | 10-13 |
| Mango | 10-13 |
| Papaya | 7-13 |
| Passion fruit | 10 |
| Pineapples | 7-13 |
| Plantains | 13-15 |
| Pommelo | 7-9 |
| Rambutan | 12 |
| Sapodilla | 15-20 |
| Sugar apples, custard apples | 7 |
| Yam | 15 |

**Chilling injury symptoms**

1. Failure of the fruit to ripen, a good example is mature green tomato when kept in refrigeration for few days.
2. Softening of the fruit, common in all sensitive crops.
3. Loss of flavor and aroma, most easily observed in guava maintained at 8°C or less for few days.
4. Increased decay in all sensitive crops (especially with Alternaria fungi)
5. Browning of the skin (such as in banana).
6. Off-flavor production in several fruits and vegetables.

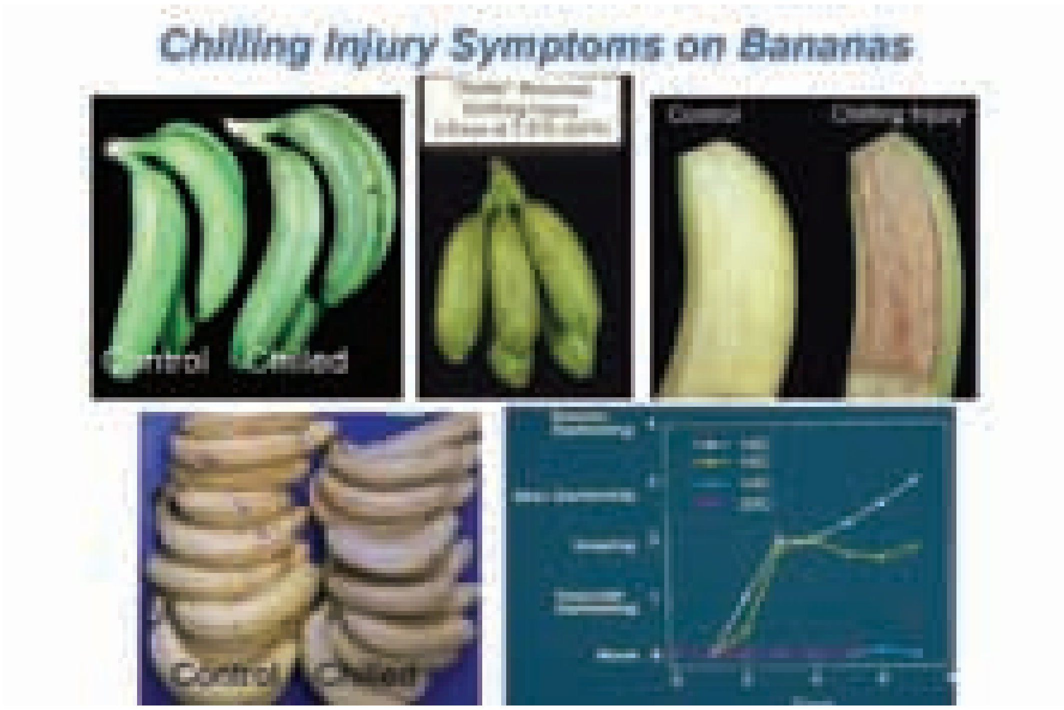

Figure 4. Chilling injury symptoms in banana (Dr. A.A. Kader).

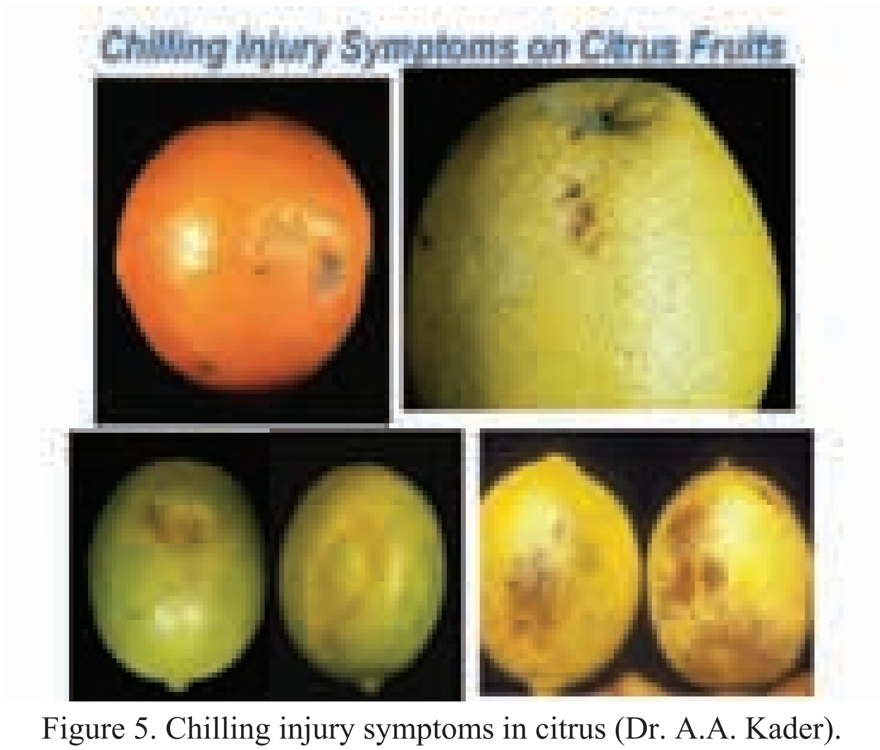

Figure 5. Chilling injury symptoms in citrus (Dr. A.A. Kader).

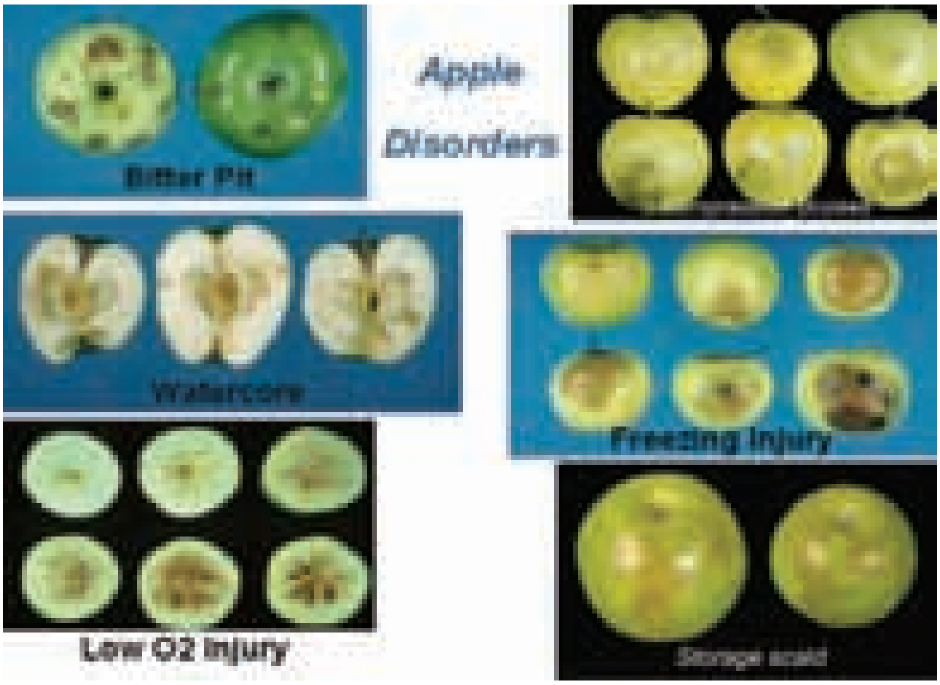


Figure 6. Different physiological disorders in apples (Dr. A.A. Kader).

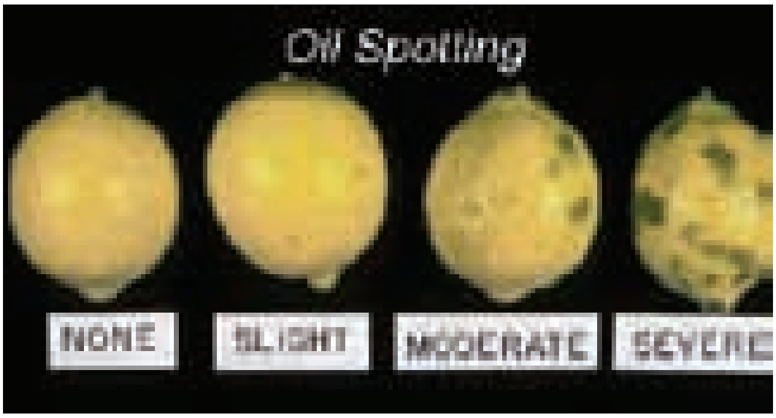


Figure 7. Oil Spotting in lemons (Dr. A.A. Kader).

**Heat injury**

Exposure of horticultural crops to high temperatures (such as during exposure to direct sunlight, or during non refrigerated storage or transport) can increase their temperature very significantly and can cause major qualitative and quantitative losses. Temperatures higher than optimum will increase the activity of the metabolism and will shorten the life of the fruit. Several fruits will fail to ripen after exposure to 35-40ºC (due to inhibition of ethylene synthesis). Higher temperatures will cause the death of the tissue.

**Mineral nutritional disorders**

Several disorders can appear in fruits and vegetables before or after harvest due to nutrient deficiency, such as:

**Calcium deficiency disorders**. Some of the common disorders due to calcium deficiency include bitter pit of apples, cork spot of pears, blossom end rot of tomatoes and blackheart of cabbage. Bitter pit is a very serious disorder that causes major losses, and usually appears after a certain period in storage. Apple cultivars differ in their susceptibility to this disease. Control measures for bitter pit include selection of resistant cultivars, preharvest and postharvest application of calcium, harvesting at optimum maturity and use of controlled atmospheres.

**Boron deficiency disorders**. This disorder commonly appears as cork-like areas in the flesh of some fruits, usually at harvest, and can be prevented with the application of borax sprays.

**Storage disorders**

Several disorders are associated with long-term storage such as superficial scald and water core in apples. Superficial scald is caused by the oxidation of alpha-farnesene, and can be avoided by the application of antioxidants such as diphenylamine and ethoxyquin.

**Ethylene disorders**

Several disorders are caused by ethylene including toughness of asparagus spears, loss of green color in many fruits and vegetables, bitter flavor in carrots, russet spotting in lettuce, sprouting in potatoes, etc.

**Disorders due to toxic chemicals**

Several chemicals, used during the handling of horticultural crops, can cause disorders. These chemicals include chlorine, ammonia, $SO_2$, methyl bromide, $Ca_2Cl$, etc. Symptoms usually appear as dark spots on the surface of the product due to the death of the tissue.


Figure 8. Greening in potato tuber (Dr. A.A. Kader).

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# POSTHARVEST PATHOLOGY

Several diseases infect horticultural crops and cause major losses. Some of the most important postharvest diseases are shown in Table 1. Some infections are initiated before harvest, although most of these pathogens can also invade the commodity after harvest, especially through wounds.

**Table 1.** Some of the most important diseases of horticultural crops.

| Crop | Disease | Causal agent |
|---|---|---|
| **Preharvest infection** | | |
| Apple | Lenticel rot | *Cryptosporiopsis malicortics* |
| Citrus fruits | Stem end rot | *Phomopsis citri*, *Diplodia natalensis* |
| | | *Alternaria citri* |
| Grapes | Gray mould rot | *Botrytis cinerea* |
| Papaya | anthracnose | *Colletotrichum gloeosporioides* |
| Peach | brown rot | *Monilinia fructicola* |
| Mango | anthracnose | *Colletotrichum gloeosporioides* |
| Strawberries | gray mould rot | *Botrytis cinerea* |
| **Postharvest infection** | | |
| Apples | blue mould rot | *Penicillium expansum* |
| Citrus fruits | green mould rot | *Penicillium digitatum* |
| | Blue mould rot | *Penecillium italicum* |
| Peach | Rhizopus rot | *Rhizopus stolonifer* |
| Banana | crown rot | *Colletotrichum musae* |
| | | *Fusarium roseum* |
| | | *Verticillium theobromae* |
| | | *Thielaviopsis paradoxa* |
| Pineapples | black rot | *Thielaviopsis paradoxa* |
| Vegetables | bacterial soft rot | *Erwinia carotovora* |

Several factors can contribute to the resistance of horticultural crops to disease infections, including:

1. Structural factors: cutinized epidermis, suberin, wax coatings.
2. Physiological factors: such as phenolic compounds, alkaloides, low pH in the sap.
3. Biochemical factors: such as phytoalexins.

**Control factors**

**Pre-harvest control**:

1. Sanitation
2. Chemical application.

**Postharvest control**:

1. Avoidance of mechanical damage.
2. Sanitation: chlorine (adding calcium or sodium hypochlorite to water), sodium orthophenyl phenate (SOPP), quaternary ammonium compounds, formaldehyde, nitrogen trichloride.
3. Temperature: low, high.
4. Relative humidity.
5. Modified/controlled atmospheres: low $O_2$, high $CO_2$.
6. Chemical treatments.
7. Irradiation.


Figure 1. Some avocado postharvest diseases (Dr. A.A. Kader).

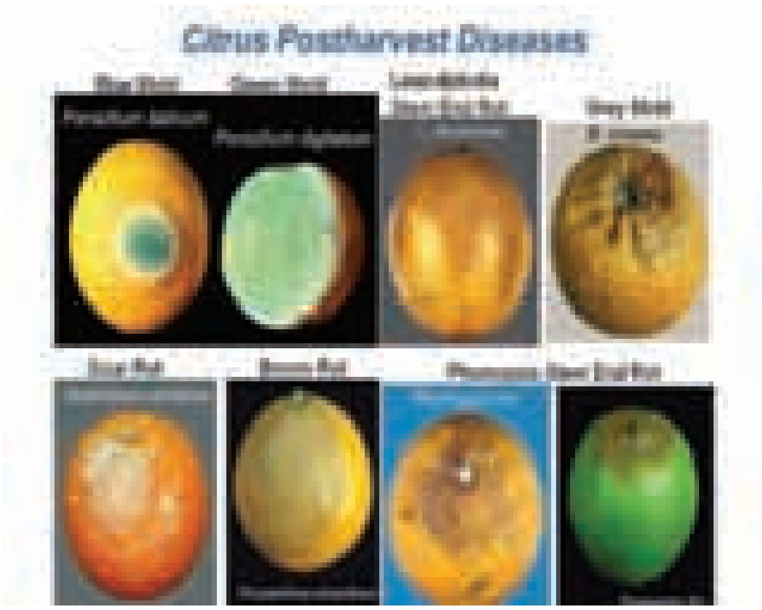


Figure 2. Some citrus postharvest diseases (Dr. A.A. Kader).


Figure 3. Some pomegranate postharvest diseases (Dr. Elhadi Yahia).

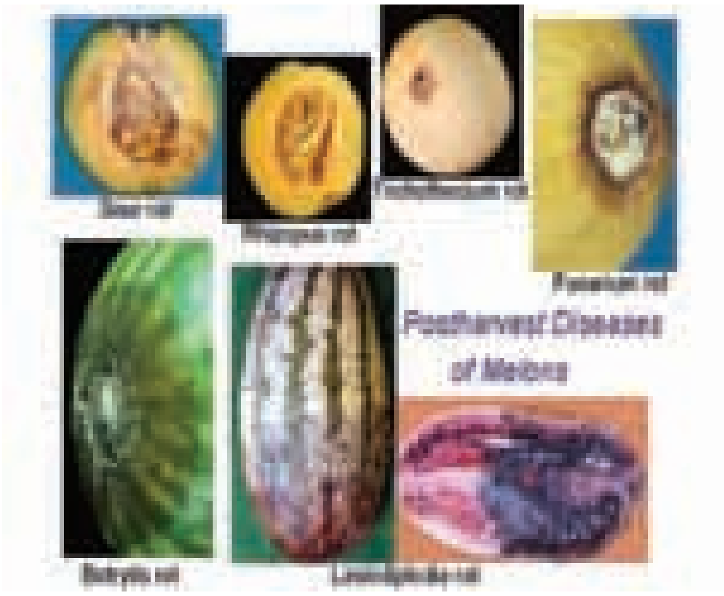


Figure 4. Some melons postharvest diseases  (Dr. A.A. Kader).


Figure 5. Some strawberry postharvest diseases (Dr. A.A. Kader).

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# MINIMALLY PROCESSED PRODUCTS

"Minimally processed", "fresh cut", "lightly processed", "partially processed", "fresh processed", are similar terms used to denote fresh fruits and vegetables converted from whole to fresh cut products. This process usually involves cleaning, washing, trimming, coring, slicing and shredding.

Production of minimally processed fruit and vegetables has dramatically increased in the recent years in the world market. They include several products such as shredded lettuce and cabbage, washed and trimmed spinach, vegetable salads and snacks, carrots or celery sticks, cauliflower or broccoli florets, peeled and sliced potatoes or oranges, chilled slices of fruits such as peach, mango, melon, peeled and cored pineapple, etc. Lettuce, the most common fresh cut product, is prepared and sold as salad with or without other vegetables such as carrot or cabbage Figs 1a and 1b.

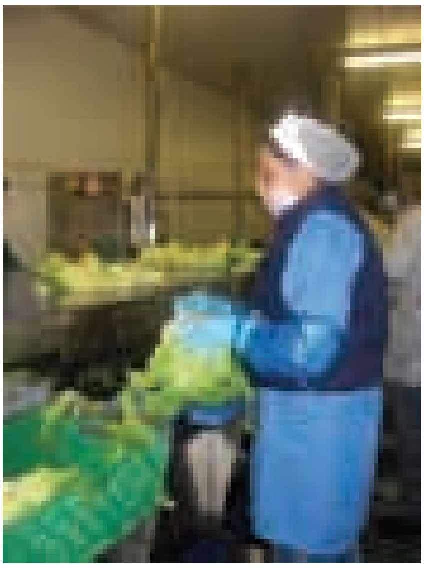

Figure 1a. Preparations of lettuce (Dr. E.M. Yahia).

Figure 1b. Processing lettuce for minimal (Dr. E.M. Yahia).

"Minimally processed" products are usually more perishable than the original whole products. Minimal processing increases respiration rate, ethylene production and deterioration rate. In addition, microbiological concern is a major problem in these products. Minimally processed lettuce is a difficult product to handle due to brown discoloration of the cut surfaces when it is stored for several days, and other deterioration processes. Another very usual difficulty to extend the shelf life of shredded lettuce for more than one week consists of the microbial flora. Human and plant pathogens are an important concern.

Strict temperature control during all the process and afterward during handling of the product is the most important factor for reducing deterioration factors and, most importantly, to reduce the microbial potential hazard. Temperature should always be at 0-4ºC.

Microbiological problems can increase in the packaged product due to increased relative humidity and decreased $O_2$ concentration. Package materials most commonly used include polyvinylchloride (PVC) for over wrapping, and polypropylene and polyethylene for bags. Package materials should be characterized with high permeability. Reasonably low concentrations of $O_2$ and/or reasonably high concentrations of $CO_2$ (depending on the type of product) are important to reduce deterioration factors and to prolong the shelf life of these products.

Figure 2a. A package of minimally processed vegetables (Dr. Elhadi Yahia).

Figure 2b. Salad minimally processed packages (Dr. Elhadi Yahia).

Hygienic procedures should be controlled very well during all the process. Effects of the chemical treatment could be more important than gas composition. Chlorine treatment can reduce browning of shredded lettuce. 50 ppm chlorine and 200 ppm citric acid are efficient in reducing leaf edge browning. $Ca(OCl)_2$ is more effective than NaClO in reducing browning of sliced potatoes and apples, possibly due to a direct inhibitory effect of Ca on polyphenoloxidase. Chlorine at pH 11 is more effective than at pH 7 in reducing browning, expressed as change in lightness of potato slices, while pH 4 is more effective with apple slices. Chlorine at 140 ppm is about as effective as 3.2% ascorbic acid, 200 ppm metabisulfite, or 200 ppm 4-hexylresorcinol on potato, but metabisulfite and 4-hexylresorcinol are more effective than chlorine or ascorbic acid in reducing browning on apple.

Calcium maintains firmness of sliced strawberries and pears. Sliced Anjou pears can have browning-free color for 30 days by dipping in 1.0% ascorbic acid and 1.0% calcium lactate, and texture can become soft with juice leakage, and the combination treatment of 0.01% 4-hexylresorcinol, 0.5% ascorbic acid and 1.0% calcium lactate could provide 15 to 30 days shelf life for Anjou, Bartlett, and Bosc pears when the pears were sliced at average ripeness of 43, 49, and 38 Newton respectively, with 2 min dipping, partial vacuum packaging, and storage at 2 to 5°C.


Figure 3a. A package of minimally processed salad (Dr. Elhadi Yahia).

Figure 3b. Packing of minimally processed salad (Dr. Elhadi Yahia).

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# PROCESSING

As most of fruits and vegetables can not be consumed immediately after harvest, part of the production is commonly either stored or processed for further use.

**Raw materials for processing**

In contrast to storage of fresh products, processing involves the alteration of the structure of the commodity. The inactivation of enzymes within the tissue inhibits metabolic activity and changes in crop composition. Processing operations tend to control the development of microorganisms present on or inside the raw material.

Availability of raw material of good quality year round is the prerequisite condition for commercial processing. As fruits and vegetables are very perishable, during the peak season of production, important quantities are either stored or pre-processed for further use throughout the year.

Raw materials for processing require the following operations:

- Adequate selection of maturity and avoiding mixing fruits and vegetables with uneven ripening. Over-ripe crops are easily damaged and decayed. Such products can not withstand different operations of slicing, cutting, pre-treatments, etc. While non mature products lack adequate flavor, aroma, texture and they will not be suitable for processing.
- Elimination of products with major external blemishes, bruising, discoloration and insect infestation.
- Cut the product to even pieces to facilitate different operations of processing, avoiding uneven dimensions (thickness, surface, size etc.).
- Reduction of time from preparation to processing to avoid discoloration or browning of the cut tissue (using blanching, dip in sugar or salt solution, smoke with sulfur, etc.)

**Pre-treatments of raw materials**

1. Sulfuring/sulfiting

Pretreatments of fruits after peeling and slicing with sulfur dioxide ($SO_2$) gas or dipping in a solution of sulfites prevent browning and loss of flavor. These changes can also be prevented by blanching of vegetables. Sulfur dioxide is obtained from burning sulfur in a closed chamber or cabinet. Sulfite solution is obtained by dissolving sulfur dioxide in water. Different solutions of sulfites including sodium sulfite, sodium metabisulfite and potassium metabisulfite can be made. Sodium bicarbonate and calcium chloride are also used to prevent discoloration. The amount of sulfur to be used and time of exposure depend on the product to be processed, the method of processing and the regulation of each country.

Figure 1a. Dried apricot.

Figure 1b. Dried peach.

**Table 1.** Sulfuring treatment and blanching (min) for some fruits and vegetables.

| Product | $SO_2$ or blanching (minutes) | Drying Temp. °C | Drying Duration (hours) | Yield (%) |
|---|---|---|---|---|
| Banana | 15 - 30 | 55 - 91 | 18 - 20 | 14 - 20 |
| Grape | 30 | 66 - 82 | 20 - 30 | 21 - 27 |
| Apples | 15 - 30 | 60 - 71 | 6 - 10 | 10 - 15 |
| Beans | blanched in steam for 3 - 6 min | Dried until beans become brittle | | 7:1 |
| Bitter-gourd | blanched in boiling water for 7 - 8 | 66 - 71 | 7 - 9 | 16:1 |
| Eggplant | 0.5% $SO_2$ for 1.5hr then blanched in boiling water for 4 - 5 min | 49 - 54 | 9 - 11 | 33:1 |
| Cabbage | 5 – 10 min. in steam or in boiling water plus 2% sodium bicarbonate for 2-3 min | 60 - 66 | 12 - 14 | 18:1 |
| Carrot | blanched in boiling water of 2 to 4 strength for 2 to 4 min | 68 - 74 | 14 - 16 | 18:1 |
| Okra (lady's finger) | blanched in boiling water for 4 - 8 min or 2 - 5 min in steam, rinsed in cold water | 63 - 68 | 6 - 8 | 12:1 |
| Potato | blanched in boiling water for 3 to 5 min | 60 - 66 | 7 - 8 | 7:1 |
| Pumpkin | placed in 2% common salt solution for 10 min, then blanched for 3 to 4 min in 2% common salt | 65 - 71 | 9 - 11 | 22:1 |
| Spinach | blanched for 4 to 5 min | 63 - 68 | 7 - 8 | 22:1 |
| Tomato | scalded in boiling water for 30 to 60 sec | 60 - 65 | 9 - 10 | 27:1 |
| Cauliflower | blanched in boiling water for 4 to 5 minutes, steeped in 0.5% $SO_2$ solution for 1hr then drained and washed | 60 - 66 | 10 - 12 | 35:1 |

**Table 2.** Preparation of sodium metabisulfite with water to obtain ppm sulfur dioxide ($SO_2$).

| **Sodium metabisulfite** | | **ppm $SO_2$** |
|---|---|---|
| **Grams/ liter of water** | **Grams/ 20 liters of water** | |
| 1.5 | 30.0 | 1000 |
| 3.0 | 60.0 | 2000 |
| 4.5 | 90 | 3000 |
| 6.0 | 120 | 4000 |
| 7.5 | 150 | 5000 |
| 10.5 | 210 | 7000 |

**2. Blanching**

Blanching of vegetables inactivates enzymes and prevents discoloration and loss of flavor and texture. Blanching can also disinfects the raw materials. Micro-organisms can be destroyed by heat. Vegetables are blanched by exposure to hot steam or dipped in boiling water for few minutes. Vegetables are cooled just after removal from hot water or hot steam. Time required for blanching depend on the commodity and the thickness of slices and pieces and the method used for blanching. It is longer for steam blanching than water blanching.

**Table 3.** Blanching times for different vegetables.

| **Commodity** | **Blanching time (min)** | |
|---|---|---|
| | **Hot water** | **Steam** |
| Leafy vegetables | 1.5 | 2 - 2.5 |
| Sliced beans | 1.5 - 2 | 2 - 2.5 |
| Squashes | 1.5 - 2 | 2.5 |
| Cabbage | 1.5 - 2 | 2.5 |
| Peas | 2 | 3 |
| Carrots | 3.5 | 3 - 3.5 |
| Cauliflower | 3 - 4 | 4 - 5 |
| Potatoes | 5 - 6 | 6 - 8 |

**Different processing methods**

**1. Drying/dehydration**

Fresh fruits and vegetables have high water content which varies from 80 to 90% for fruits and higher for most vegetables. Drying or dehydration is the process by which the horticultural crop is forced to lose rapidly part of its water content to a desired level (< 10%) which will not be suitable for growth and development of micro-organisms. Dehydration significantly reduces the weight and the volume of the product which will have an important impact on packaging material, transport cost and on keeping quality. Dehydrated or dried products can be stored for longer periods than fresh crops if adequate packaging and keeping conditions are used. The process of dehydration can be achieved by sun-drying, heat and freezing.

Main factors that have direct effect on dehydration rate of the product:

- Type of dehydrator and source of heat
- Type of product and its texture
- Evaporative surface area of the piece to be dried
- Thickness of the pieces

- Temperature of drying
- Humidity of the warm air
- Air distribution and its velocity
- Air pressure inside the dryer and surrounding the product to be dried or dehydrated

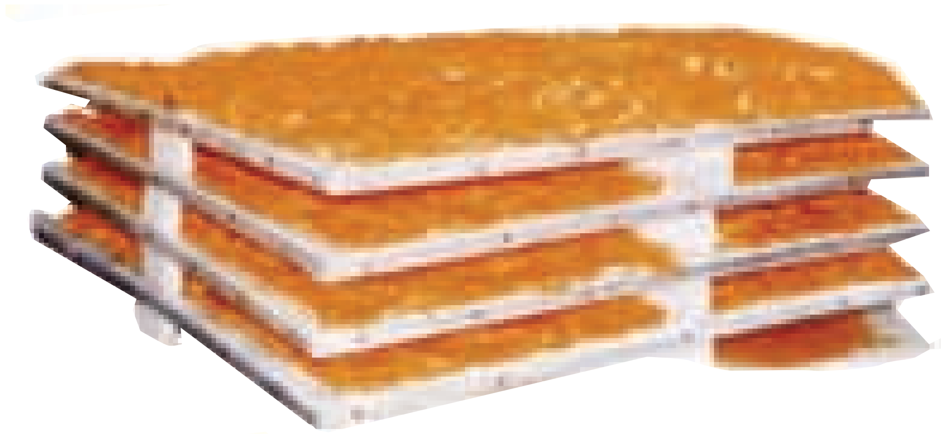

Figure 2a. Pieces of mango ready for drying (Dr. Elhadi Yahia).

*Figure 2b. Dried mango.*

Figure 2c. Dried banana.

Figure 3. Metal detector in packages of processed fruits (Dr. Elhadi Yahia)

**2. Concentration**
Concentration of fruits and vegetables can be obtained by heat dehydration. It is important to control the rate of heating in order to prevent burning of the product which will affect its flavor and quality. Tomato, orange, apple concentrates are the main examples of preservation by concentration. Processed tomato can be concentrated to 32 or 36 ºBrix instead of 4 to 6 ºBrix of fresh tomato. Concentration reduces weight, transport cost, storage and packaging.

**3. Pickling**
Preservation of fruits and vegetables in salt, vinegar and / or acetic acid associated with spices and edible oil is termed pickling. The three preservatives are either used singly or in combination. There is a large variety of pickles from several crops (mango, lime, cucumber, olives, turnip, okra, cauliflower, carrots, radish, etc.). Pickles are made either at home or at large scale commercial processes. The nutritional value of pickles varies with raw material type and the method of preparation.

**4. Freezing**
Low temperature (-18ºC or lower) are used for frozen products. At this temperature very little changes can occur in the commodity. Before freezing the products, mainly vegetables, are subjected to blanching technique to inactivate enzymes. Then the products are frozen as quickly as possible either after packing or in bulk. The faster the freezing the best will be the quality of frozen product.

Freezing is widely used for a large number of vegetables such as peas, beans, carrots, potato, radish, corn, cauliflower, broccoli, etc. The products can be packed individually or can be mixed in the same packages. Different combinations of frozen vegetables can be found in the market.


Figure 4b. Frozen mango
(Dr. Elhadi Yahia)

Figure 4a. Frozen avocados
(Dr. Elhadi Yahia).

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# CHAPTER TWO

# POSTHARVEST HANDLING OF FRUITS

# Apple (*Malus* x *domestica* Borkh.)

Figure 1. Different types of apples (Dr. E.M. Yahia)

**Quality characteristics**

Apple consumers demand excellent appearance, texture, firmness and flavor. fruit skin color ranges from green or yellow for varieties such as 'Golden Delicious' and 'Granny Smith' to red in 'Red Delicious.', and some cultivars are bi-colored such as in 'Gala' and 'Braeburn'. High quality apple should be free from blemish, although there may be a greater tolerance for defects in certain markets such as organic, although with the increase in organic production this is changing rapidly. Firmness is a very important quality attribute in all cultivars. Fruit should be crispy and crunchy, although firmness may vary from one cultivar and another. A crisp 'Granny Smith' apple is often 80 to 98 Newton while a crisp 'Golden Delicious' is above 50 Newton. Sweetness and acidity are important for apple flavor, but they vary by variety. For example, soluble solids content of 'Fuji' apples can be 20%. Acidity of 'Granny Smith' apples is high (0.8 to 1.2%), but that of 'Red Delicious' is low (0.2 to 0.4%).

**Respiration and ethylene production**

Apple is a climacteric fruit, with an increase in ethylene and carbon dioxide production during ripening. The timing of the climacteric and ripening of apple fruit is advanced by ethylene application. Prevention or slowing of ethylene production, by inhibiting ethylene synthesis or action delays fruit ripening and increases storability, and this can be achieved in different ways, such as by the use of low temperature, modified or controlled atmosphere, and 1-methylcyclopropane (1-MCP).

**Maturity indices**

Apple fruit harvested before optimum maturity will have poor color and flavor and can be more susceptible to physiological disorders such as bitter pit and superficial scald. Over-mature fruit will be softer, more easily damaged, become more susceptible to disorders such as watercore and senescent breakdown, and diseases. Storage period can be increased by harvesting fruit before they are fully mature, but quality characteristics such as flavor may not develop adequately. Therefore, it is important to determine the appropriate harvesting time depending on the different uses of the fruit, such as immediate sales and consumption, prolonged storage period or processing.

A wide range of indices (firmness, total soluble solids, days from fruit set, carbon dioxide production, etc) have been tested as possible indicators of harvest maturity. Ethylene (internal) production and the starch index have become the most widely used maturity indices. However, relationships between ethylene production and optimum harvest dates can be poor, and may not be adequate in some cultivars. For some bi-colored apples, background color is considered an important harvest index. It is important to keep in mind that no single maturity index is appropriate for all cultivars, and therefore a combination of indices should be used.

Other indices such as flesh firmness and total soluble solids content (TSS) are quality indicators rather than maturity indicators, as they are greatly influenced by orchard factors. During fruit maturation firmness falls and sugar content continues to increase, and they provide information that can be important to fruit performance in storage.

Figure 2. Apple packing in Jordan (Dr. Elhadi Yahia).

**Packaging**

Fruit sizing is usually carried out by weight or diameter but is independent of grade. Requirements for fruit size vary greatly by market, but in general larger sizes bring greater returns. Apples are most often packed on 4 to 5 soft fiberboard trays made from recycled newspaper. In some cases, the tray may be made of soft polystyrene. Cartons are often un-vented, however, un-vented cartons on pallet stacks will cool slowly, detrimentally affecting product storage life and quality. A two-layer carton that is wider, known as the 60 x 40 pack, is becoming more common in some countries, with the advantage of minimizing fruit handling as the cartons are placed directly onto display racks at retail. Most apples are sold loose, although fruit are increasingly available in polyethylene consumer of 1-5 kg. Shrink-wrapped packages reduce the time consumers spend in the produce section, and also reduce loss caused by consumer sorting and handling of individual fruit.

**Physiological disorders**

Several physiological disorders affect apple fruit, but susceptibility varies by variety, pre-harvest factors and postharvest conditions. They can be classified as:

Figure 3. Apple packages (Dr. Elhadi Yahia).

Watercore is an important disorder that develops before harvest, in which intercellular air spaces in the core and cortical tissues become filled with a liquid, predominantly sorbitol. Commonly the presence of this disorder is associated with advanced fruit maturity and low night temperatures prior to harvest, but sometimes it can occur as a result of heat stress. Presence of watercore in fruit at harvest creates problems in certain varieties such as Delicious because fruit with moderate or severe watercore can develop breakdown during storage. Severely watercored fruit should not be stored in controlled atmosphere (CA) storage because the breakdown will develop over time.

Bitter pit is another important apple disorder that can develop on the tree or during storage. It is characterized by development of discrete pitting of the cortical flesh. The pits may occur predominantly near the surface or deep in the cortical tissue. The incidence and severity of bitter pit depends on the variety, harvest date and climate In susceptible varieties, harvest of less mature fruit, excessive pruning, high temperatures and/or droughty conditions during the growing season can result in higher incidence. Effects of climatic conditions are at least partly related to low calcium concentrations in the fruit. Prediction of risk based on mineral (mainly low calcium) content at harvest or infusion of magnesium is an important prevention strategy. Rapid cooling, CA storage, and application of postharvest calcium drenches may reduce its occurrence. Recommended rates for application of calcium vary by variety and region. Preharvest applications of calcium can be far more effective than postharvest drenching for increasing calcium concentration in fruit calcium and reducing bitter pit.

Senescent breakdown occurs during storage mainly due to harvesting over-mature fruit and/or fruit with low calcium content, and can be increased by storing fruit at higher than optimal temperatures. The incidence of this disorder can be reduced by harvesting fruit at a less mature stage, drenching with calcium before storage, rapid cooling and reducing storage duration.

Superficial or storage scald is a physiological disorder associated with long-term storage, and susceptibility depends on variety, climate, and harvest date. Diphenylamine (DPA) is an effective control and is usually applied with a fungicide to reduce decay incidence, and calcium salts may also be included at the same time to reduce bitter pit or senescent breakdown. Ethoxyquin is no longer permitted for use on apples. Low levels of $O_2$ and low ethylene in CA storage can reduce the risk of scald developing.

Soft scald is characterized by irregular but sharply defined areas of soft, light brown tissue that may extend into the cortex, and susceptibility depends on variety and climate. Over-maturity 'Golden Delicious' apples can induce the disorder. Storing fruit at slightly higher temperatures (3°C) can sometimes control the disorder. DPA may also reduce incidence of soft scald.

Low temperature breakdown, brown core and internal browning are chilling related disorders.

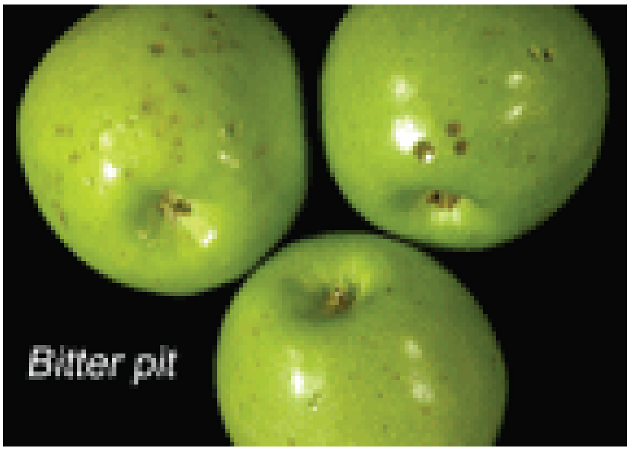


Figure 4. Bitter pit
(Source: Dr. A. Kader, U.C. Davis)

Figure 5. Apple scald
(Source: Dr. A. Kader, U.C. Davis)

Low $O_2$ injury in apples can cause loss of flavor and fermentation, which may be eliminated if problem is identified soon enough and severe injury has not occurred. Injury symptoms range from purpling or browning of the skin in a red colored variety, to development of brown soft patches resembling soft scald, to abnormal softening and splitting of fruit. $CO_2$ injury can be expressed as wrinkled, depressed colorless or colored areas restricted to the skin surface, mostly on the greener side of the fruit, and also as brown heart and/or cavities in the flesh. DPA can reduce the incidence of $CO_2$ injuries.

**Postharvest diseases**

Some of the pathogens that can infect fruit in the field but remain latent or quiescent until after harvest include *Colletotrichum* species that cause bitter rot, *Botryosphaeria* species that cause black rot and white rot, and *Pezicula malicortis* that cause bull's eye rot. Important postharvest diseases in apples include blue mold caused by *Penicillium* species and gray mold caused by *Botrytis cinerea*, blue mold being the most common and destructive. *Penicillium* invades the fruit primarily through cuts, stem punctures, and bruises. Field control is done using fungicides and other pre-harvest disease management strategies. Blue mold and gray mold can be controlled with the applications of thiabendazole (TBZ), benomyl, and thiophanate-methyl, although the use of benomyl and thiophanate-methyl is not allowed anymore. TBZ is usually applied immediately after harvest in combination with the antioxidant DPA, and a second time as a line spray or in wax as apples are packed. Captan is moderately effective for controlling *P. expansum* and *B. cinerea*, but captan residues are not acceptable in some markets. Some biocontrol agents can be effective, but they generally cannot provide eradicant activity against established infections. Good sanitation, careful fruit handling, reduced mechanical damage, rapid postharvest cooling, and storage at recommended temperatures can reduce postharvest decays.

**Cooling and storage conditions**

Apple fruit respond dramatically to both temperature and atmosphere modification and control. The rate of cooling of apple fruit affects retention of quality, but its importance varies according to variety, harvest maturity, nutritional status of the fruit and storage. It is very important to rapidly cool apple varieties that mature in the early part of the harvest season (summer varieties) since they will soften more rapidly than those that mature in the later part of the harvest season. Within a variety, apples tend to soften more rapidly at later stages of maturity than earlier stages. Effects of slow cooling are magnified as storage length increases. For example, a 1-day delay at 21°C before cooling results in a 7 to 10 day loss of storage-life for 'McIntosh' apples. The effects of delays before cooling of fruit, irrespective of timing of CA establishment, are shown for 'Empire' apples in Table 1.

Figure 6. Grey mold on apples (Source: U.C. Davis)

**Table 1.** Effect of cooling rate on firmness of rapid CA Empire apples.

| **Days to cool to 0°C** | **Days from Harvest to 3% $O_2$** | **Flesh firmness (N) at removal from CA** |
|---|---|---|
| 1 | 4 | 63 |
| 7 | 4 | 58 |
| 14 | 4 | 52 |

Apple fruit can be cooled by room cooling, forced-air cooling, or hydro-cooling. Forced-air cooling and hydro-cooling systems are very efficient to rapidly reduce fruit temperatures, but they are not widely used for apples. Room-cooling is the predominant method, although this method is slow and inefficient. Rapid cooling is often difficult to accomplish when rooms are filled rapidly and refrigeration capacity was not designed for a large fruit load. This problem can be overcome by loading fruit into a number of rooms for pre-cooling before moving into long-term storage, or to load only the quantity that can be handled by the refrigeration system of the room. When refrigeration capacity is a limiting factor, no more than two stacks of bins should be placed across the width of the storage room each day, and that should be reduced to one stack if the air temperature in the room is not down to 0 °C by the next morning.

The recommended conditions for commercial storage of apples are -1 °C to 4 °C and 90 to 95% RH, depending upon variety (Table 2).

**Table 2.** Storage characteristics of several apple varieties.

| Variety | Potential storage life at 0ºC, months | | Susceptibility to scald | Comments |
|---|---|---|---|---|
| | In air | In CA | | |
| Braeburn | 3-4 | 8-10 | Slight | Sensitive to $CO_2$. |
| Cortland | 2-3 | 4-6 | Very high | Temperature sensitive; McIntosh conditions preferred; Scald inhibitor essential. |
| Delicious | 3 | 12 | Moderate to very high | Sensitive to $CO_2$ > 2%; Scald inhibitor essential. |
| Empire | 2-3 | 5-10 | Slight | Avoid late harvest; Temperature sensitive; Scald inhibitor not required. $CO_2$ sensitive. |
| Fuji | 4 | 12 | Slight | Late harvested fruit may be $CO_2$ sensitive. |
| Gala | 2-3 | 5-6 | Slight | Loses flavor during storage. |
| Golden Delicious | 3-4 | 8-10 | Slight | Susceptible to skin shrivel. |
| Granny Smith | 3-4 | 10-11 | Very high | Sensitive to $CO_2$. |
| Idared | 3-4 | 7-9 | Slight | Temperature sensitive; Tolerant to orchard freezing damage. |
| Jonagold | 2 | 5-7 | Moderate | Avoid late harvest; May develop scald. |
| Jonamac | 2 | 3 | Moderate | Loses flavor during storage. |
| Law Rome | 3-4 | 7-9 | Very high | Scald inhibitor essential. |
| Macoun | 3 | 5-7 | Slight | Can be stored with McIntosh. |
| McIntosh | 2-3 | 5-7 | Moderate | $CO_2$ sensitive; Normal storage is sometimes shortened by excessive flesh softening; Scald inhibitor recommended in regions other than the Champlain. |
| Mutsu | 3-4 | 6-8 | Slight | Green apples have low eating quality. |
| Spartan | 3-4 | 6-8 | Slight | Can be susceptible to high $CO_2$. Susceptible to skin shrivel at 36 to 38 °F. |
| Stayman | 2-3 | 5-7 | High | Will tolerate $CO_2$ up to 5% but usually stored in 2 to 3% $CO_2$. Scald inhibitor essential. Susceptible to skin shrivel. |

Most apple cultivars are not sensitive to chilling injury and storage at the lowest possible temperature (0°C) is important to maintain fruit quality (firmer and greener fruit), but some varieties (such as McIntosh) are sensitive to chilling and can develop core browning, soft scald and internal browning when held at temperatures below 3 °C. Low temperature disorders are typically developed when fruit are kept for more than several months, and therefore the risk of low-temperature injury are low for fruit kept for short period (2 to 3 months). Varieties that are susceptible to low temperature injury should be stored at 2 to 3°C.

**Controlled atmosphere (CA)**

Apples are the most important horticultural commodity stored under CA conditions. The gas composition and storage temperature conditions are specific depending on variety, growing region, and sophistication of the equipment available for monitoring and controlling the atmospheres. Safe low $O_2$ concentration depends on cultivar and region. For example, Delicious apples from British Columbia, Canada can be stored safely at 0.7% allowing control of superficial scald without use of diphenylamine (DPA), but fruit of the same cultivar from other growing regions may show injury when stored at these low $O_2$ levels. Temperatures should be increased for fruit stored in low $O_2$ CA, because lower temperatures increase risk of low $O_2$ injury. Low ethylene CA storage (< 1 ppm or 1 $\mu L\ L^{-1}$) was used in New York State for storage of the naturally low ethylene-producing 'Empire' apple, but it has been replaced by low $O_2$ storage. Very low (0.25 to 0.5%) $O_2$ concentration for up to 2 weeks can control superficial scald in some cultivars. High $CO_2$ (15 to 20%) treatments before application of CA storage were used for maintenance of firmness of 'Golden Delicious' apples in some regions.

**1-Methylcyclopropene (1-MCP)**

1-MCP can reduce softening, yellowing, respiration, loss of titratable acidity, and development of several physiological disorders, however it can also inhibit volatile production, and this effect depends on type of cultivar and fruit maturity.

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# Apricots (*Prunus armeniaca*)

Figure 1. Apricot fruit

Apricot is a climacteric fruit where respiration and ethylene production increase with maturation and ripening.

**Quality characteristics and criteria**

Fruit size, shape, freedom from defects (including gel breakdown and pit burn) and decay are important quality criteria. High consumer acceptance in some countries is usually high for fruit with higher than 10% soluble solids, and about 0.7 to 1.0% titratable acidity. Most cultivars soften very fast making them susceptible to bruising and subsequent decay. Fruit should be uniform in size, and not more than 5% by count of fruit in each container may vary more than 6-mm when measured at the widest part of the cross section.

**Maturity indices and harvesting**

Fruit, especially those for distant shipping, should be picked when still firm because of their high bruising susceptibility when fully-ripe and soft. In several regions, harvest date is determined by changes in skin ground color from green to yellow (see figure 2), but the exact yellowish-green color depends on cultivar, growing region and shipping distance.

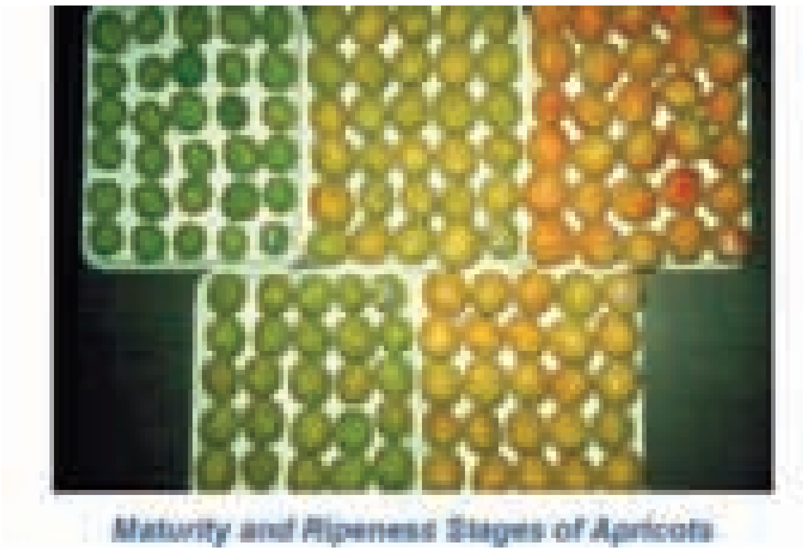


Figure 2. Maturity and ripeness stages of apricots (Dr. A.A. Kader).

Apricots are commonly hand harvested, placed into picking bags or plastic totes. Half bins (up to 200 kg of capacity) are some times used in some countries to collect harvested fruit in the field.

**Packaging**
Fruit is commonly packaged in single and double layered trays, or volume-filled (about 10 kg net).

**Optimum storage conditions**
Apricots can be kept for 1-4 weeks, depending on cultivar, at -0.5 to 0ºC and 90-95% RH, although the fruit is seldom stored commercially in large quantities. Controlled atmospheres (2-3% $O_2$ + 2-3% $CO_2$) can retain fruit firmness and ground color, although only have very moderate commercial benefits and are not used commercially for storage but may be used for transport. Oxygen concentration should not be lower than 1% as it may result in development of off-flavors, and $CO_2$ concentration should not be higher than 5% to avoid flesh browning and loss of flavor, especially when transport period is more than 2 weeks.

**Physiological disorders**
Chilling injury (gel breakdown) in sensitive cultivars can be expressed as gel breakdown, flesh browning and loss of flavor, and it develops more rapidly at 2.2 to 7.6ºC than at 0ºC. This disorder is characterized in early stages by the formation of water-soaked areas that subsequently turn brown, and breakdown of the tissue is sometimes accompanied by sponginess and gel formation. Therefore, storage and transport at 0ºC is important to minimize incidence and severity of chilling injury on susceptible cultivars.

Pit burn is a disorder, where the flesh tissue around the stone softens and turns brown when the fruit is exposed to temperatures above 38ºC before harvest, and the injury increases with higher temperatures and longer exposure durations.

**Postharvest diseases**
Brown rot, caused by *Monilia fructicola*, is the most important postharvest disease of apricot, where infection begins during flowering, and fruit rots may occur before harvest, but often occur after harvest. Control measures include orchard sanitation to minimize infection sources, pre-harvest fungicide application and fast cooling after harvest.

*Rhizopus* rot, caused by *Rhizopus stolonifer,* occurs frequently in ripe or near-ripe fruit held at 20 to 25ºC, and it can be controlled by fast cooling to 4ºC or lower and holding at a temperature as close as possible to 0ºC.

Figure 3. Apricot fruit infested with fruit fly.

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# Bananas (*Musa spp.)*

Banana is a climacteric fruit that are commonly harvested mature green and ripened later, because banana ripened on the plant often split, have poor texture, and tend to be mealy. Fruit respiration rate is about 10-30 ml $CO_2$/kg/hr at 13$^oC$ and 20-70 mI $CO_2$/kg/hr at 20$^oC$, and ethylene production is about 0.3-10 ml/Kg/hr at 20$^oC$.

Early on during the development of the fruit, the bunches should be covered with perforated polyethylene bags (Figure 1). The top of the bag should be secured to the stalk. These bags are important to prevent blemishes and scars in the fruit caused by leaves. In addition, a pesticide can be placed in the bag to reduce insect damage. The age of the fruit is usually recorded by using ribbons of different colors.

**Quality indices**

Quality indices for bananas include finger length and form, and freedom from defects such as insect injury, physical damage, scars, and decay. Several factors can reduce the quality of banana fruit including skin abrasions, bruising, and decay. Abrasions result from skin scuffing against leaves or other fruits or surfaces of the packages or of handling equipments. The exposure to low relative humidity less than 90% increases water loss from scuffed areas, and promotes the development of brown to black color.

**Maturity indices and harvesting**

The adequate maturity index for banana is the degree of fullness of the fingers, which is indicated by the disappearance of angularity in a cross section.

Harvesting of the bunches need to be done by 2 persons; one person cuts the bunch and the other person receives it (Figure 2).

Figure 1. Covering banana with plastic bags (Dr. Elhadi Yahia).

Figure 2. Harvesting banana (Dr. Elhadi Yahia).

**Transport to the packinghouse**
Bananas are transported to the packinghouse as bunches. It is very important to reduce physical injury to the fruit during harvesting and transport. In small operations, bunches should be transported in one single layer, and with adequate material that can serve as a cushion. In bigger operations, bunches are transported with the use of different systems of cableways. The bunches are attached to the cable by its base, and should be separated by spacer bars to prevent their contact.

**Packing and packaging**
Upon arrival to the packinghouse, the fruit should be inspected for finger fullness and length, bruises, blemishes, scars, insect attacks, and decay. Only fruits that meet the quality grades should be accepted and packed. Inferior quality fruit can be sent for processing.

Bananas are then dehanded using a sharp curved knife, and immediately placed in a water tank (Figure 3). Water is needed to coagulate the exuded latex and thus reduce the staining. In addition, water serves to eliminate dust and dirt, and partially cools the fruit. Fruit is commonly placed in a second water tank for 10 to 15 minutes to further eliminate the latex.

Figure 3. Washing banana for packing (Dr. Elhadi Yahia)

Antioxidants and/or a fungicide can be added to the second water tank to reduce oxidation (darkening) of the cut surfaces and the development of decay organisms. Thiabendazole and Imazalil are the commonly used fungicides for banana. Sodium hypochlorite at a concentration of 75 to 125 ppm is also commonly added to the water to reduce decay organisms. Water should be changed regularly to avoid the increase of inoculum. Chlorine concentration in the water should be monitored regularly using indicator papers. Fungicides can also be added separately after washing either as spray or dip.

The most common package used for banana is a corrugated fiberboard carton lined with polyethylene, with a capacity of 18 kg. Boxes are then palletized and either stored in a cold room, or loaded into a pre-cooled transport container.

**Optimum conditions for storage and transport**
Optimum holding temperature is 13-14$^{o}$C and optimum relative humidity is 85-90%. Maintaining adequate air circulation during storage and transport is very important to maintain adequate and uniform temperature and gas concentration.

**Modified and controlled atmospheres**
Modified (MA) and controlled (CA) atmospheres are very effective for delaying the ripening and for prolonging the postharvest life of mature-green bananas. These techniques are commonly used, especially during marine transport of bananas. The most common technique used is called "Banavac", which comprises in packing the fruit in a polyethylene liner of about 0.04 mm thickness, then the bag is evacuated, commonly using a house vacuum cleaner, and sealed. Only

green fruit should be used, and it is essential to avoid punctured bags. Ideal gas concentrations are 2-5% $O_2$ and 2-5% $CO_2$. MA and CA reduce respiration and ethylene production rates. Potential postharvest life of mature-green bananas are 2-4 weeks in air and 4-6 weeks in MA/CA at 13-14$^{o}$C. It is important to avoid the exposure of fruits to concentrations less than 1 % $0_2$ and/or higher than 7% $CO_2$, which may cause fermentation, undesirable texture and flavor.

**Chilling injury**

Bananas are very sensitive to chilling injury (CI), when the fruit is exposed to temperatures below 13$^{o}$C. CI symptoms include surface discoloration, dull or muddy color (instead of the bright yellow color), subepidermal tissues reveal dark-brown streaks, failure to ripen, and flesh browning, in severe cases. CI symptoms can appear after exposure to low temperature for a few hours to a few days, depending on cultivar, conditions and handling practices before harvest, maturity stage, and temperature. For example, moderate chilling injury will result from exposing mature-green bananas to one hour at l0$^{o}$C, 5 hours at 11.7$^{o}$C, 24 hours at l2.12$^{o}$C or 72 hours at 12.8$^{o}$C (Figure 4). Low temperature injured fruits become very sensitive to mechanical injury.

Figure 4. Effect of temperature on banana fruit (Dr. A.A. Kader)

**Postharevst diseases**

Important pathological disorders that can affect banana fruit include crown rot, anthracnose, stem-end rot, and cigar-end rot. Crown rot is caused by one or more of the following fungi: *Thielaviopsis paradoxa, Lasiodiplodia theobromae. Colletotrichum. musae, Deightonjella torulosa, and Fusarium roseum*. These attack the cut surface of the hands, and the fungi grow from the rotting hand tissue into the finger neck, and down into the fruit. Anthracnose is caused by *Colletrichum musae*, and becomes evident as the bananas ripen, especially in wounds and skin splits. Stem-end rot is caused by *Lasiodiplodia theobromae* and/or *Thielaviopsis paradoxa*, which enter through the cut stem or hand. The invaded flesh becomes soft and water-soaked. Cigar end rot is caused by *Verticillium theobromae* and/or *Trachysphaera fructigena*, where the rotted portion of the banana finger becomes dry and tends to adhere to the rest of the fruit, and appears as the ash of a cigar.

**Ripening**

Banana should be green and firm on arrival to destination. Ideal conditions for artificial ripening are as follows:
Temperatures: 15-20$^{o}$C.
Relative humidity: 90-95%
Ethylene concentration: l00-150 ppm, which can be provided using ethylene cylinders or Ethylene generator (Figure 5).

Figure 5. Ethylene generator for banana ripening (Dr. Elhadi Yahia).

Ethylene is applied, preferably every 12 hours, for 24 to 72 hours depending on fruit maturity stage, and desired speed of ripening. Ripening rooms should be well ventilated before each ethylene addition. Carbon dioxide concentration should be kept below 1% to avoid ripening inhibition. Ripening rooms should be well insulated and sufficiently airtight. Adequate air circulation is needed to provide uniform temperature, and to eliminate the build- up of gases (ethylene and $CO_2$). The ripening process should be controlled depending on the initial stage of maturity of the fruit, the desired final maturity stage, the market demand, and the consumer preference. These aspects can be easily controlled by manipulating the temperature, ethylene concentration, and exposure duration (Table 1).

Ethylene at a concentrations of 3 to 34% in air by volume (30,000 ppm or higher) is explosive. The maximum concentration needed for ripening is very low compared to the explosive range, but care should be taken to secure its safe use.

Table 1. Temperature program for different ripening duration.

| **Dayes** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
|---|---|---|---|---|---|---|---|---|
| **4-days schedule** | 17.8°C | 17.8°C | 16.7°C | 15.6°C | | | | |
| **5- days schedule** | 16.7°C | 16.7°C | 16.7°C | 16.7°C | 15.6°C | | | |
| **6- days schedule** | 16.7°C | 16.7°C | 15.6°C | 15.6°C | 15.6°C | 14.4°C | | |
| **7- days schedule** | 15.6°C | 15.6°C | 15.6°C | 15.6°C | 15.6°C | 14.4°C | 14.4°C | |
| **8- days schedule** | 14.4°C | 14.4°C | 14.4°C | 14.4°C | 14.4°C | 14.4°C | 14.4°C | 14.4°C |

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# Citrus

Citrus fruits are non-climacteric and can not be artificially ripened after harvest, although color can be changed. Respiration rate (2-4 ml/ $CO_2$/kg at 20 $^oC$) and ethylene production (0.1 ML $C_2H_4$) are low and therefore it can be stored for prolonged periods of time after harvest.

Figure 1. Some types of citrus fruits (Dr. Elhadi Yahia).

**Nutritional values**

Citrus fruits are rich sources of vitamin C in addition to their important content of folic acid, β-carotene (pro-vitamin A) and flavanoid compounds. Some flavanoids are known as anti-oxidants for inflammation and allergy in addition to their action against cancer and viruses. Citrus fruits are also known as a rich source for pectins present either in edible and/or non-edible part of the fruit. Pectins have positive effects on health as they control glucose absorption in association with lower insulin in blood serum. Palmonoids compounds, constituents responsible for bitter and astringe taste in citrus are believed to have beneficial effects on human health as they reduce tumors occurrence.

**Maturity indices**

The most important maturity indices in citrus are total soluble solids/acid rate (8:1 or more) and yellow coloration of not less than 25% of fruit rind, or total soluble solids/acid, with greenish yellow color at 25% or more of fruit rind. Sometimes fruit juice content can be considered as maturity index, with no less than 30%.

**Quality indices**

The most important quality indices in citrus are color density and uniformity of fruit rind, fruit size, shape, rind texture, flavor, freedom of deterioration and infestation, including freedom from physical injuries scratches, mechanical damages, rind mis-shaping (malformation) and color loss, frost-deterioration, cold-injury and insects damage. Fruit flavor is referred to total soluble solids content/acid and to the absence of undesired taste compounds.

Figure 2. Open market for citrus in Libya (Dr. Elhadi Yahia).

**Harvest and packing**

Citrus harvest is made manually, using mobile ladders and stages to pick fruits. It is important to use special shears for this purpose. After harvest, fruits are usually transferred to packing houses for sorting, washing, grading, waxing and packing. Packing house can be as simple as a field house or it can be a large and well equipped and computerized one, where fruits can be categorized according to consumer interests.

Usually citrus fruit are packed in woody or plastic boxes of 6-20 kg, but bags are also used for local markets. Export packing is usually made in straw compressed wood of 19-20 kg. Sometimes, fruits are individually packed in 0.01m plastic films to retain fruit moisture, such a method would control the diseases spread by microorganisms among fruits particularly when fungicides are used before wrapping and packing.

**Storage and shipping conditions**

Some citrus cultivars can be stored on the tree for several weeks. In general, the optimal storage and shipping temperature is 3-8$^{o}$C according to cultivar. Relative humidity should be around 90-95%. Storage and shipping duration ranges from 3 to 8 week depending on cultivar, temperature and site of orchard.

**Physiological disorders**

Citrus fruits are sensitive to cold injury expressed by fruit pitting, brown color in addition to fruit deterioration. The minimum temperature for fruit cooling depends on cultivar, production site and maturity stage at harvest. It is possible to minimize cold injury by keeping relative humidity in storage atmosphere at the highest possible level, in addition to wrapping fruits with wax film and use of fungicides such as Thiabendazole which may control cold injuries.

Rind breakdown is expressed at fruit peduncle end and at picking region, where symptoms appear as wilting and breakdown in the rind and as it continues breakdown reaches fruit neck or peduncle.

Disorders lead to undesired coloration results from late fruit harvest where fruit exceed the optimal picking stage, but $GA_3$ (gibberllic acid) can reduce this problem.

Oily scars (stains) result from harvesting and handling of swelling rind and glands.

Rough handling may rupture oil glands on fruit rind, and therefore, orange fruit should not be harvested when full turgid or swelling at early morning or right after rains or irrigation. Packing of the fruits should be done after a curing period, which will result in rind curing and hardening to avoid injuries.

**Postharvest diseases**
Some of the important fungi causing diseases in citrus include *Penicillium digitatum* (green mold), *P. italincum* (blue mold), stem end rot caused by *Phomopsis citri*, brown rot caused by *Lasiodiplodia theobromae*, and bitter rot caused by *Geotrichum candidum*. Green and blue molds are widely spread at citrus production regions but more severe at arid regions than humid ones whereas stem end rot caused by *Phomopsis* in addition to *Alternaria* spp. are spread in humid regions.

Some effective control measures include avoiding physical (mechanical) injuries during harvest and handling, reduction of fungal disease severity in surrounding atmosphere, fungicides and biological control treatments, keeping optimum temperature and relative humidity during storage and shipping and marketing at the optimal condition, ethylene removal and the use of hygiene regulation during handling processes. Some chemical treatments that can be used include sodium carbamate, borax, thiabendazole, benomyl, imazalia, 2-aminobutane, biphyenyl and 2,4-D.

**Insects infestation**
Some treatments are used to control insects such as fumigation with methyl bromide and phosphine, in spite that such treatments may cause plant phytotoxicity. Fumigation with methyl bromide is applied at $48g/m^2$/for 2 hours at $21^oC$. In some countries, citrus fruit may be treated at low temperature: $1.7^oC$ for 14 days or $2.2^oC$ for 16 days, but such a treatment may cause some injuries so before treatment, curing at high temperature is needed to promote fruit resistance to cold.

Figure 3. Citrus package.

**Degreening**

In some regions where there is no sufficient difference between day and night temperatures, citrus fruit may not acquire good coloration, and therefore degreening treatments are needed. Yellow and orange colors are commonly produced when cool nights are followed by hot days (significant difference in temperature between day and night). Degreening removes chlorophyll, which is linked to flavedo pigment; but do not affect fruit internal composition. This treatment may speed up senescence and deterioration. Degreening conditions include treatment with ethylene at 1-10 ppm at 20-25$^{o}$C for 1-3 days and 90% relative humidity, and keeping $CO_2$ at 0.1% or less.

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# Dates (*Phoenix dictylifera* L.)

The date palm (Nakhla in Arabic) is the tree of life. It is widely distributed, but is grown largely in the Middle East and North Africa where about 80% of the world total number of trees and 75% of the world total date production are found. The leading countries in date production in the region are Iran, Egypt, Iraq, Pakistan and Saudi Arabia.

Date palm is a multiple purpose tree for the following:
A significant earner of foreign revenue for both small and large farmers.
Its valuable by-products as building materials and versatile starting material for handicrafts.
Its significant contribution towards the creation of equable microclimates within oasis ecosystems, thus enabling agricultural development to be sustained in many drought and saline-affected regions,
Refuse and inferior dates are used as livestock feed supplement,
The secondary product generated from fruits such as syrup, jam and baby food, give the tree much added value.

Figure 1. Date season in Tunisia (Dr. Elhadi Yahia).

**Nutritional value**
Date fruit play an important role in the nutrition of human population of the region. The fruit is noted for its nutritional quality and source of energy due to its high sugar content, which comprise up to 70% of the fruit. Dates are also good sources of iron, potassium, calcium, manganese, copper and phosphorous, along with various vitamins including thiamine, riboflavin, biotin folic acid. Moreover the fruit is known for its low fat and sodium.

**Fruit development and maturation**
Fruit developmental stages are usually divided to five, known by their Arabic terms; "hababouk", "kimri", "khalal", "rutab", and "tamar". The color of the fruit changes from green to yellow, pink, red, or yellow spotted with red depending on cultivars. During the "rutab" stage, the fruit softens and the color turns to light brown, the fruit starts to loose weight and accumulates more sugars, mainly reducing sugars.

Figure 2. Two types of dates (Medjool and Zahidi).

During the stages of "khalal and "rutab", fruits loose progressively their water content and starch is converted to sugars. The "tamr" is the late and the ripening stage of development. Most of the dates are harvested in the "tamr" stage, when the fruit has about 60 to 80% sugar content, depending on locations and cultivar. At this stage, fruits can be harvested soft, semi-dry or dry, depending on type of variety, destination and use.

Figure 3. Covering fruit with paper for protection (Source: USDA).

**Harvesting**
Harvesting season extends from July to late November according to cultivar and location. Early harvest is commonly practiced to take advantage of higher prices in the market, to avoid adverse weather conditions, cracking and splitting of fruits, excessive dehydration for early maturing fruits, insect infestation, and attack of micro-organisms. Time of harvest is based on sugar content, moisture content, date appearance, and texture. Some varieties with low tannins but rich in sugar can be harvested at the "khalal" stage (called "balah" in North African countries and "bisr" in Oman); for other varieties, dates harvested before full maturity must be ripened artificially. Very immature dates may not be properly ripened artificially and consequently will be of poor quality. 'Deglet Noor' dates should not be harvested before the turning stage in which the texture is yielding to pliable and the color is amber to cinnamon. Fruits will have a better storage potential when harvested with a reddish ring at the perianth end than when it is left on the palm until the ring has faded with more advanced maturity. 'Hallawi' dates should not be harvested before the soft ripe stage. 'Maktoom' and 'Boufgouss' dates can be harvested when 10-25% of the surface is translucent, and then can be ripened to an acceptable quality.

Figure 4. Tamar stage (USDA).

**Ripening**
Dates may need to be ripened after harvest when picked earlier to avoid damage by rain, insects or other factors. Ripening rooms should be equipped with means to control temperature, humidity and adequate air circulation. The exact temperature and time of ripening should be decided depending on the type of dates, maturation stage and condition at harvest. A temperature of 4O-43°C is recommended to ripen 'khadrawy', 'Kustawy', 'Hayani', 'Sayer', 'Khalasa' and 'Sphinks' dates. 'Deglet Noor' dates should not be ripened at temperature higher

than 35°C to avoid fruit darkening and loss of flavor. Soft cultivars such as 'Hallawi', 'Dayri' and 'Zahdi' can be ripened at slightly higher temperatures (35-38°C). Ripening of these cultivars is complete in about 2 to 4 days when they had lost their translucency and little or no hard tissue remains. Temperatures of 45-46° C and 70% RH for a period of 2-4 days or longer are required to ripen cultivars with thick flesh such as 'lteema', 'Maktoom' and 'Saidy'. In North African countries where the weather is hot and the air is dry enough, dates are harvested and immature fruits are ripened in open air either in the sun or under the shade. Fruits are separated individually and spread on the ground or kept on the bunch until ripened progressively. Although this technique is simple and cheap, fruits exposed in the open air are subjected to different adverse conditions such as rain, dust from winds, bird's attacks, rodents, etc.

**Quality criteria**

High quality fresh dates is attributed to adequate size and color, small pit, thick flesh, free from dirt, sand and leaves particles, birds, insects and rodents' damages, fungi and molds infestation, sugar crystals formation and freedom from any other apparent alterations. The skin of dates should be smooth, with little or no shriveling, golden-brown, amber, green or black color depending on varieties. The texture may be soft and syrupy, or firm or dry depending on the cultivar. Quality grades for dates are based on uniformity of color and size and absence of defects or damages by discoloration of the flesh, rupture of the skin, deformity of the fruit, puffiness of the skin, scars, sunburn, insect damage, decay, black scald, fermentation, improper ripening, mechanical damage, dirt or any other foreign material. In general, the total sugars for different grades are usually the same when expressed as a percentage of dry weight, but the higher grades usually contain higher amount of sugar per date.

**Packing and packaging**

Fruits of different varieties do not ripen concomitantly. Thus, the first postharvest handling operation consists of separating ripe dates from immature ones or from those that are damaged during harvesting by insects, birds, rodents, transport, etc.

Dares should be cleaned from undesirable particles that stick to the date skin. Cleaning can be achieved by (i) blowing air on the fruits, brushing softly the dates to avoid damages of the skin or by (ii) washing the fruits with running water. Dates can also be cleaned by passing them over damp toweling or with the use of washers. Spray jets can be used for soft dates instead of washers. Germicides are used to reduce microbial activity; moist dates after washing are air-dried from excess water before packaging.

Figure 5. Sorting of dates (source: USDA).

Dates are sorted to remove culls and to separate them to uniform sizes (Figure 5). Sorting can be executed manually or mechanically on crates or moving belts. Dates can be sorted according to maturity, flesh consistency, color, shape and size. Within different groups, dates are separated according to quality. Discarded fruits consist of dates with defects and abnormalities such as oparthenocarpic fruits, immature or overripe, mechanical damages during harvest or on the palm, damage by birds or insects, physiological and pathological disorders.

Sizing is done manually or mechanically to separate dates according to their size and weight. Uniformity of size in a package is one of the quality criteria for dates. Date size varies according to the variety. 'Medjool' dates in the USA are classified into 3 size categories: “Jumbo” for less than 25 dates per Kg (> 40 gram / fruit), “Mixed” for 25 to 35 dates per Kg and “Conventional” grade for more than 35 individual dates per Kg.

Surface-coating is done to reduce stickiness and improve appearance. Several materials have been recommended for this purpose including solutions of 5% or 6% soluble starch as dip, 3% methyl cellulose, or a combination of 2% butylated hydroxyanisole, 2% butylated hydroxytoluene, 6% vegetable oil, 90% water and wetting agent.

Dates are packaged in several type and size packages. Some dates are marketed in 7-8 kg flats of fiberboard or wood, others in 2-5 kg cartons. Large reinforced cartons are used for packing of dry dates, especially for export. Consumer packages are widely used for dates and are made of a number of sizes and shapes. They include bags of transparent film, or trays over wrapped with films. Round fiberboard cans with metal tops and bottoms containing 500-1000 g are also used. Rigid transparent plastic containers with a capacity of 200-300 g are commonly used. Small consumer packages (50-60 g) are also in use. For storage, dates can be packed according to destination. A wide range of package sizes and materials can be found in the major producing areas.

**Optimum storage conditions**

Date fruits are easy to store when they contain 20% moisture and proper temperature of 0 to 1°C and 60/65% relative humidity are used. Pathological and physiological deterioration increases with increasing moisture content and storage temperature. Very soft and syrupy dates are subjected to mold invasion and fermentation more than other types of fruits. Relatively small differences in moisture content may have an important effect on the keeping quality of 'Deglet Noor' fruit. At 24°C, 'Deglet Noor' dates show darkening of the skin 4 times faster when stored at 24% than at 20% moisture content. Relative humidity during storage should be controlled according to fruit initial moisture content to avoid excess drying or gaining of moisture. Generally, relative humidity of 75% or lower is recommended for fresh varieties in storage. At high relative humidity, dates will absorb moisture from the air unless they are packaged in moisture-proof containers. Temperature has an immediate effect on the keeping quality of dates. Storage at ambient or higher temperatures tends to reduce the shelf life of the fruit. Cold storage temperatures tend to reduce the rate of deterioration, slows down biochemical metabolism, color changes and maintains high pH of dates. At 0°C, dates can be stored in good conditions for up to 12 months but some varieties may develop sugar spots or crystals. Fully mature soft and firm 'Deglet Noor' dates can be kept for more than a year when stored at -17.5°C but will not stand more than one month at 27°C, 3 months at 15°C and 8 months at 5°C. Partially dried dates can be held for a year at 0°C or lower, or for few weeks at ambient temperature. Dry dates can be held at room temperature for years without significant quality losses. Dates can readily absorb odors and thus should not be mixed in storage or during long transport with garlic, apples, onions and potatoes or other foods with strong odors. Ripe dates at "rutab" or "tamr" stages, commonly harvested and handled in the world market, are not sensitive to chilling and freezing temperatures. However, freezing temperatures can injure dates at early stages of "kimri" and "khalal".

**Physiological disorders**

Darkening is a major problem in dates. Its rate varies with cultivar, temperature, moisture content, and it is affected by several treatments. It can be reduced by storage in low temperature, low moisture content, or in an inert gas. Temperatures above 60°C cause a reddish color and increase the astringincy and off-flavors in 'Deglet Noor', which might be due to breakdown products of the insoluble procyanidin tannins.

Blacknose or sugartip is a severe checking of the skin in some cultivars (especially in Deglet Noor). It is induced by high humidity just before the beginning of the "khalal" stage and characterizes by darkening, shriveling, and hardening of the flesh at the tip of the fruit. Black scald is characterized by a blackening of the flesh and sunken area with a definite line of demarcation at the tip or on the sides of the fruit. Puffiness or sunken separation is caused by high temperature and/or high humidity before the beginning of ripening, may increase during curing and affects only soft cultivars. This disorder becomes severe when the separated skin from the flesh in a balloon-like fashion, becomes hard and brittle. Sugar spotting is characterized by light-colored spots under the skin and is restricted to the invert sugar dates. Almost all dry cultivars and several of the semi-dry cultivars contain large amounts of sucrose and are less sensitive to sugar spotting. In 'Deglet Noor', sugar crystals may form within the flesh when the dates become old. Sugar spotting decreases as the temperature decreases and when the moisture falls below 22%. Sugar spots affects the appearance and texture of the fruit, they can be removed by warming, but can reappear if unfavorable conditions prevail.

**Diseases**

The most common diseases of dates includes fermentation by yeast (most important) and molding by fungi. Steam-hydrated dates are more resistant to attack by micro-organisms than natural or non-hydrated dates because of the partial sterilization of steam dehydrated fruit. Yeast that can be found on dates are those capable of growing on a relatively concentrated sugar solutions such as Zygosaccharomyces and Hansenula. The formation of gas pockets under the skin, white aggregates of yeast cells, discolored flesh and alcoholic odor characterize the infested dates.

Fungi that commonly attack dates include *Aspergillus* sp., *Alternaria* sp, *Stemphylium*, *Botryosum*, *Cladosporium* sp., *Macrosporium* sp., *Citromyces ramosus*, *Phomopsis diopspyri* and *Peniciluim*. These fungi may cause significant losses before or just after harvest during rainy or high humidity periods, and can attack fruits at 'khalal" or "rutab" stages. However, most of these fungi, except *Catenularia fuliginia* Saito, will not be able to grow on dried dates.

**Insects**

Several insects can cause serious damage on fruits at different developmental stages. *Oligonychus afrasiaticus* McGregor and *O. pratensis* Banks are mites known as "Bou Faroua" disease, which affect the fruits at the "hababouk" stage. The larvae develop around the fruit with white filament netting, which in turn causes fruits to drop prematurely. Same consequences are caused by *Coccotrypes dactyliperda*, which lead to fruit drop at immature green stage. *Parlatoria blanchardii* attacks the fruit while still green and form white filaments around the fruit, which reduces respiration and photosynthesis and fruits do not reach maturity. Date or carob moth (*Ectomyelois ceratoniae* Zeller) is another Lepidotera widely present in different producing areas of dates and causes important postharvest losses on stored dates. Several other insects such as *Batrachedra amydraula* Meyr, date stone beetle (*Coccotrypes dactyliperda* F.), *Carpophilus hemipterius*, *Carpophilus multilatus*, *Urophorus humeralis*, and *Heptoncus luteolus* can cause serious damages for dates on the bunch or after harvest. Other pests include *Vespa orientalis*, *Cadra figulilella*, *Arenipes sabella* and mushroom mite (*Tyrophagus lintaeri* Osborn) can infest stored dates.

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# Fig (*Ficus carica* L.)

Figs are climacteric and are slightly sensitive to ethylene action, stimulating softening and decay severity, especially if kept at 5ºC or higher. Fully mature fresh figs are soft, easily bruised, and highly perishable.

**Quality characteristics**
Skin color and flesh firmness of fresh figs are important quality characteristics. Flavor is influenced by stage of ripeness. Overripe figs can become undesirable due to fermentative products. Other important quality characteristics indices include absence of defects such as bird-peck, sunburn, scab, skin break, and stem shrivel, insects, and decay.

**Maturity indices**
Fresh figs are commonly harvested when almost fully ripe and firm. Skin color and flesh firmness can be used as ripening indices. Figs for drying should fully ripen and partially dry on the tree before harvesting and completion of drying to about 17% moisture using either solar drying or a dehydrator at 60ºC.

**Harvest and packaging**
Figs are hand-picked and commonly packed in a one-layer box. Pickers wear gloves as a protection against fig juice.

**Storage conditions**
Fast pre-cooling using forced-air cooling to 0ºC is important for maintaining figs quality. Optimum storage and transport conditions are 0ºC and 90 to 95% RH. Modified and controlled atmospheres containing 5-10% $O_2$ + 15-20% $CO_2$ are effective for decay control, firmness retention, and reduction of respiration and ethylene production. Postharvest life at optimum temperature and RH depends upon cultivar and ripeness at harvest, is from 1-2 weeks in refrigerated regular air storage and 3-4 weeks in CA. Figs should be displayed at 0-2ºC and 90 to 95% RH.

**Physiological disorders**
Figs are not chilling sensitive, but extended storage in CA can result in loss of characteristic flavor where figs exposed to less than 2% $O_2$ and/or higher than 25% $CO_2$ develop off-flavors due to fermentative metabolism.

**Postharvest diseases**

Alternaria rot, caused by *Alternaria tenuis* appears as small, round, brown-to-black spots over the fruit surface, and cracks on the skin make the fruit more susceptible to the rot. Black mold rot, caused by *Aspergillus niger*, appears as dark or yellowish spots in the flesh with no external symptoms, and at advanced stages the skin and flesh turn slightly pink color and white mycelia with black spore masses follow. Handling figs adequately to avoid infection with *Aspergillus* species is very important to minimize formation of mycotoxins. Endosepsis (soft rot), caused by *Fusarium moniliforms*, appears in the cavity of the fig making the pulp soft, watery and brown with sometimes an offensive odor. Souring is a pre-harvest problem resulting from yeasts and bacteria carried into figs by insects, especially vinegar flies, resulting in odors of alcohol or acetic acid. Control measures to reduce diseases include controlling orchard insects, using effective control of pre-harvest diseases, enforcing strict sanitation of picking and transporting, supervising careful handling to minimize abrasions, cracks, and other mechanical damage, avoiding picking figs for fresh market from the ground, fast cooling to 0ºC and maintaining the cold chain. Solar heating reduces insect infestations in ripening and drying figs.

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# Grapes (*Vitis vinifera* L.)

Figure 1. Grapes harvesting (Dr. Rawya Basiouny)

**Quality indices**

Grapes are non/climacteric fruit, and therefore they should be harvested at optimal ripening stage where clusters are fully formed, berries are uneasy to loose, compact and have natural color particularly at stem end junction. In addition, berries should be uncracked, free from diseases, free from physiological disorders as sunburn and petiols and peduncles are green.

**Harvesting**

Grapes do not ripen after harvest and therefore they should be harvest at full ripe stage, which can be achieved by:

1. Color: full color according to cultivar.
2. Total soluble solids (TSS) content: grapes should be picked when TSS reaches 14-20% depending on acidity, but at less than that value they would not be very edible and marketable. If harvest is delayed, berries would be loose, petioles dry and fruit sensitive to rots. Sometimes harvest can be delayed for few days when humidity is high or during rainy season to avoid diseases infestation. After harvest, diseased and damaged clusters should be sorted away and immature berries and clusters should also be discarded.

Temperature is an important limiting factor, and high temperature can lead to:

a) Increase in diseases incidence particularly during transport and storage.
b) Peduncles dryness, their color change and berries looseness.
c) Berries wilting particularly at their junction to peduncle.

Temperature during the summer (harvest time) can reach up to 40$^{o}$C, and berries temperature may exceed air temperature particularly in dark and colored cultivars.

**To keep quality of grapes, requires:**

1. Fast pre-cooling to remove field heat in the crop and to prolong storage period.
2. Delay crop harvest at rainy times and when relative humidity is high at early morning until high humidity disappears to avoid diseases infestation.
3. Using an adequate pest management program (IPM).

**Pre-harvest treatments**

Grapes are heavily infected in the orchard by brown rot disease caused by *Botrytis cinerea*, and therefore, it should be controlled before harvest by fungicidal spray. IPM (integrated pest management) program should be employed to control diseases dominant in each country.

**Post-harvest treatments**

**Pre-cooling**

Pre-cooling is important to eliminate field heat in fruits, and hence to reduce fruit temperature to near or close to optimal storage, to reduce respiration rate and therefore reduce disease spread, weight loss, scattering or looseness of berries and to avoid peduncles dryness. Loss of 2% weight in berries leads to peduncles dryness, peduncle junction, barrier wilt and scattering or looseness which reduces fruit marketing ability. Pre-cooling can be done by "room cooling" or ideally by "forced-air cooling". Room cooling can be done in the storage rooms, preferably with high cooling capacity (efficiency) to speed up the cooling process, and pallets should be distributed in a way that can insure good air circulation. However, room cooling is not very efficient and it takes about 2-3 days. Forced-air cooling is the most commonly used for grapes. It is very efficient in cooling capacity, air circulation in addition to several vacuuming fans at different room sides. Boxes would be arranged in 2 rows at fans sides, crop is to be covered with plastic cover from the top in addition to space in between rows and the space in front of vacuuming fans. Vacuum fans will start to reduce pressure in space between boxes rows allowing the cold air to penetrate boxes from outside to inside through holes in packs. Ventilation holes should be directed to inside and outside. Air circulation speed should be very efficient to increase pre-cooling efficiency. Modern cooling rooms using this method are equipped with sulfur dioxide fumigation units to reduce disease infection.

**$SO_2$ fumigation**

Grapes are fumigated with sulfur dioxide ($SO_2$) during pre-cooling, transport or storage to reduce *Botrytis* rot. Fumigation of grapes is made at the beginning of storage using $SO_2$ at 1% for 20 minutes with strong air circulation to homogenize spread of gas and maximize treatment efficiency. Fumigation should be repeated at 0.25% during every 7-10 days. It is important to ventilate storage when fumigation is completed to remove $SO_2$ traces to avoid physiological disorder such as color change. It is important to secure high relative humidity during fumigation to maximize fumigation efficiency. $SO_2$ inhibits the growth of spores at fruit surface only and has no effect on endogenous (internal) fungi after they penetrate tissues, therefore, repeat fumigation will prevent fungal growth and disease spread.

Temperature has an important role on infection severity and degree. Grapes are infected within 18 hours on 15-20$^{o}$C whereas they get infected after 72 hours at 2$^{o}$C, and therefore pre-cooling and fumigation should be applied very rapidly. Nowadays, fumigation is made during transport using $SO_2$ generators (bags) containing tablets of sulfur metabisulfate.

Storage of other crops with fumigated grapes is not advised because most horticultural crops are sensitive to sulfur dioxide.

**Suitable storage conditions**

Ideal grape storage conditions are -1 to 0$^{o}$C and 90-95% relative humidity, for 2-6 months depending on cultivar. Emperor is a high storage ability cultivar that can be stored at -1 to 0$^{o}$C for 3-6 months. Sultania and Banaty (Thompson Seedless) grapes are considered as medium storage ability cultivars and can be stored for 1-2.5 months; Concord and Alexandria (Muscat) are unsuitable for storage.

**Physiological disorders**

Aging occurs when storage period is prolonged, where clusters loose their natural color, berries become soft and moistened with unacceptable taste, and berries color changes from red (in red cultivars) to gray purple and from green (green cultivars) to greenish gray and then brown if storage duration is prolonged, in addition to weight loss and lower marketing value.

Ammonia injury occurs as a result of ammonia leakage from cooling pipes or main tank to storage space. Increasing ammonia gas in storage atmosphere to higher than 0.8% leads to changes in berries color, so red color berries turn blue and green color turn to bluish green. Ammonia gas leakage can be detected by humans. Humans are very sensitive to ammonia showing tearing and running nose when exposed to ammonia at tenth of its harmful concentration for grapes, therefore regular checking of storage rooms and inspection of fruits are needed. In addition, it is important to try to install ammonia detectors. In case of ammonia leakage, inspection of cooling pipes and gas reservoir tank should be made very rapidly. To reduce the effect of ammonia gas, water spray in storage atmosphere can be made but to keep water away from grape crop, ammonia gas will then turn to unharmful ammonium.

**Factors that decrease grape quality after harvest**

There are several factors which lead to grape fruit quality deterioration after harvest, including temperature, relative humidity, disease infestation, rough handling and prolonged storage period.

Increasing temperature during storage leads to development of diseases particularly *Botrytis* which develops even at $0^oC$. In addition, increasing temperature leads to increasing weight loss which leads to enhancing peduncles dryness and berries wilting and scattering. Decreasing temperature to $-2^oC$ may lead to freezing injury and hence loss of marketing value, therefore, temperature should be maintained at about 0-2ºC without significant fluctuation.

Optimum relative humidity is 85-90%, and increasing it to more than 95% will promote development of diseases, whereas decreasing it will cause increasing weight loss.

Most diseases are initiated in the orchard before harvest, and therefore they should be controlled through integrated pest management programs. Sorting of fruits should be made after harvest to exclude injured clusters to prevent disease spread during storage. Pre-cooling should be done fast, and fumigation with $SO_2$ should be applied during storage and/or transport.

Rough handling particularly at harvest and transport may lead to berries damage and scattering and hence berries juice will be released which would promote a suitable medium for fungal growth and diseases, and thus lowering crop marketing value.

Prolonged storage periods will lead to wilting, scattering of berries, deterioration in color and flavor, increased weight loss and rotting.

Figure 2. Packing grapes in the field (Dr. Elhadi Yahia).

**Packaging**

Grapes layers should not be more than 2 layers in packs of 4-5 kg. Packs should have clean paper at the bottom, attractive shape, and good ventilation. Packs should also have all required information such as cultivar name, weight, source, contact, etc.

Figure 3. Grape boxes (Dr. Elhadi Yahia).

Figure 4. Grapes packing in Egypt (Dr. Rawya Basiouni).

Figure 5. Grapes packing in Egypt ()Dr. Rawya Basiouni).

Figure 6. Grapes packing in Egypt (Dr. Rawya Basiouni).

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# Grapefruit (*Citrus paradisi* Macf.)

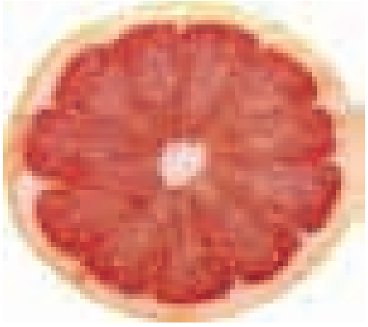

Figure 1. Grapefruit.

Grapefruit is a non-climacteric fruit with low ethylene production (< 0.1 μL/kg/hr at 20°C), and low respiration rate (< 10 mg $CO_2$ kg/hr) at optimum storage temperature.

**Quality characteristics**
A high quality grapefruit should have a turgid and smooth peel and be relatively blemish-free, with an appropriate juice content and adequate balance of soluble solids and acidity, and minimum bitterness.

**Physiological disorders**
Postharvest pitting is a peel disorder of grapefruit, which can be reduced or eliminated by reducing fruit pulp temperature to 10°C or less, and coating fruit with high gas permeable coatings. Chilling injury (CI) is promoted at low temperature (around 5°C or less). CI is characterized by peel pitting, different than those caused by high temperature. Coating grapefruit with high shine water wax reduces the incidence of CI. Conditioning of the fruit by intermittent warming or stepwise lowering of temperature can also reduce CI. Oleocellosis can occur during harvest when excessive squeezing force is used to remove fruit from the stem, and grapefruit harvested in the morning, when relative humidity is high, are most susceptible because oil glands are easily broken in turgid peel. Stem-end rind breakdown, which is associated with excessive water loss, is characterized by collapse and sinking of the peel in irregularly-shaped regions near the stem end, and late-season grapefruit are most susceptible to this disorder. Grapefruit stored longer than 6 weeks at 3°C may develop physiological collapse of juice vesicles.

**Postharvest diseases**
Stem end rots develop as latent infections on the fruit button (calyx + disc) and begin growth through the core after harvest. It develops unevenly at the stem and stylar ends resulting in wavy margins, and considered a problem with grapefruit grown in warm humid climates but not common in most Mediterranean climates. *Diplodia natalensis* is prevalent in early season fruit when temperatures are high and degreening is used. Development of *Phomopsis citri* is favored during the winter months when temperatures are low and degreening is no longer necessary. *Alternaria citri* is a less aggressive fungus that can be problematic in over-mature grapefruit and those stored for long periods. Often the symptoms of *Alternaria*, internal black discoloration generally towards the stem end, are not visible until the fruit are cut. Anthracnose caused by *Colletotrichum gloesporioides*, is a minor problem that can appear on late-season fruit. Brown rot (caused by *Phytophthora citrophthora*) appears more frequently in mature fruit and fruit stored for longer durations at low temperatures. Green and blue mold, caused by *Penicillium digitatum* and *italicum*, respectively, invade fruit through wounds made during harvesting and handling. Growth of *P. digitatum* is more favorable at temperatures above 10°C, whereas growth of *P. italicum* occurs more readily at lower temperatures. Immature fruit are resistant to

sour rot (*Geotrichum candidum*) infection, but as the fruit mature, the disease can become a problem. Consequently, late-season grapefruit can become infected, especially since the disease develops more readily at temperatures above 15°C.

The use of thiabendazole (TBZ) immediately at of the fruit to the packinghouse is recommended to control *Diplodia*, *Phomopsis*, anthracnose and *Penicillium* control. Application of aqueous imazalil or TBZ in the wax treatment is also an effective control. Minimizing degreening time by delaying harvest will assist in controlling stem end rot caused by *Diplodia* and anthracnose. Reducing mechanical injury during harvesting and handling can reduce injuries and thus pathogens entry and decay. Packinghouse space, equipments, and storage areas should be kept clean. Generally, pre-cooling or storing fruit after packing at 10°C or less is effective for the control of grapefruit diseases.

**Insect quarantine treatments**

Cold treatment is an approved quarantine treatment. It is done at 0.6 to 2.2°C for 14 to 24 days, but in areas of low fly infestation, a less stringent temperature and duration can be used. However grapefruit needs to be preconditioned at 10-15°C before the quarantine treatment in order to increase resistance to chilling injury.

**Degreening**

Degreening is necessary for fruit that do not develop adequate color, usually when night temperatures remain high. Treatment includes the application of 1 to 5 ppm ethylene at 21-28ºC and high RH (90-95%) for 12 hours to 3 days, which causes the destruction of peel chlorophyll. One complete air change per hour is needed to avoid the buildup of $CO_2$ and ethylene in the degreening room and to promote uniform temperature.

**Storage conditions**

Optimum storage and transport conditions for grapefruits are 12-15°C and 95% RH. Fruit is commonly waxed during packing to reduce water loss. However, to minimize postharvest pitting, grapefruit should be cooled immediately below 10°C with 95% RH after harvest and maintained at 5-8°C during transit and storage until distribution at retail outlets. High shine water waxes will minimize chilling injury and incorporated fungicides can control decay at these temperatures. At optimum storage temperatures, fruit respiration rates will be reduced and quality will be maintained up to 6 weeks.

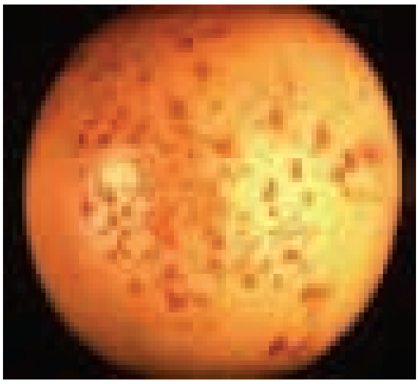

Figure 2. Chilling injury symptoms on grapefruit (Dr. Adel Kader).

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# Lemons (*Citrus limon*)

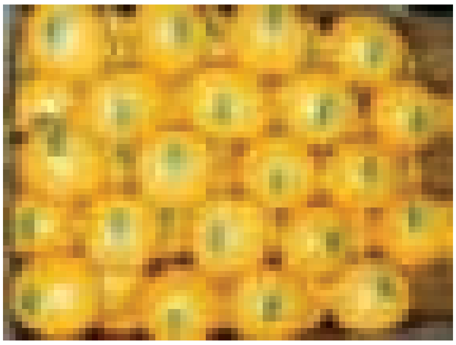

Figure 1. Lemon fruit.

Lemon is a non-climacteric fruit characterized by low respiration rate and low ethylene production.

**Quality and maturity indices**

Being a non-climacteric fruit lemons should be harvested at full ripening stage. Ripening stage can be determined through:

- Fruit reaching the specific color.
- Fruit total acidity ranging from 5 to 7%.
- Total soluble solids/acid ratio of 1:2
- Sometimes lemon fruits are picked green and then exposed to artificial coloration treatments after storage.

**Optimum storage conditions**

- Temperature: 15$^o$C
- Relative humidity: 90-95%.
- Storage duration: Lemon fruit can be stored as green mature (or greenish) for several months at the optimal conditions whereas ripe fruits are stored for about a month.

**Mixed storage with other crops**

- Storage duration is determined depending on type crop stored with lemon if mixed storage with other crops is used. Lemon fruit can not be stored for long period with high ethylene produced crops such as banana, tomato, in particular if fruits are ripe but if lemon fruits are at green stage they can be stored for longer period at 15-18$^o$C and 85-90% RH.
- Storage for short period: it is possible to store lemon fruits for short periods with banana, green tomato, potato and sweet potato at 15$^o$C and relative humidity (RH) of 85-90%.
- Storage for a long periods: lemon fruits can be stored for long periods with banana and green tomato at 15-18$^o$C and 85-90% RH.

**Harvest and preparing of fruit**

- Fruit are to be picked with short petioles (peduncles) using harvest shears then pack in field boxes and transferred to packing houses. It is very important to avoid fruit mechanical damage and therefore avoiding water loss and fungal infestation.
- Procedures applied at preparation(packing) houses:

- Fruits washing by fruits disposal in washing containers in the presence of detergents and disinfectants.
- Fruit washing by water to remove detergents and disinfectants traces.
- Treatment with fungicides.
- Sorting to exclude mis-shaped, injured and infected fruits.
- Sorting according to quality level or degree.
- Sizing according to lemon fruit size and weights:
- Packing in carton packs according to number of fruits, or size or in nested bags for consumers.
- Transfer to marketing outlets.
- Storage of green fruits while color enhancement can be achieved during marketing using ethylene at 19-21$^{o}$C and 85% RH.

**Physiological disorders:**

1. Cold injury: lemon fruits are sensitive chilling injury (CI). CI symptoms appear as dark scars (stains) with unpleasant smell and internal white membranes (albedo) that turn to reddish brown color. Usually cold injury is followed by disease development. To avoid cold injury, storage should not be at temperature less than 12$^{o}$C.
2. Oily scars: Oily scars occur when the rind is high in water, then oil of ruptured oily glands is released. This phenomenon occurs due to rough harvest and handling particularly at early morning or after irrigation or after rains. Sometimes such a disorder appears as yellowish green or brown in color. To control oily scars, fruit injury should be avoided throughout all the handling processes.

**Important diseases**

- Blue and green molds are the most important diseases that attack lemon fruits.
- Fruit end rot.

**To control disease**

1. Maintains optimal temperature and humidity.
2. Avoid mechanical injury to fruits.
3. Discard infected fruits.
4. Use suitable fungicides.

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# Mangoes (*Mangifera indica* L.)

Mango is a climacteric fruit. Respiration rate is 12-16 ml $CO_2$/kg.hr at 10°C, 15-22 ml $CO_2$/kg. hr at 13°C, and about 35-80 ml $CO_2$/kg. hr 20°C. Ethylene production" is about 0.1-0.5 µl/kg. hr at 10°C, µ0.2-1.0 l /kg. hr at 13°C, and 0.5-8.0 µl/kg. hr at 20°C.

Figure 1. Mango fruits on the tree.

**Maturity indices**

The selection and establishment of maturity indices in mango is extremely important for postharvest quality and postharvest life. Optimum maturity indices for mango depend on the cultivar, and include changes in fruit shape (fullness of the cheeks), changes in skin color from dark-green to light-green to yellow (in some cultivars), and changes in flesh color from greenish-yellow to yellow, to orange. Red blush color of the skin of some cultivars is not a dependable maturity index. Due to differences among mango types, diversity of cultivars, and diversity to production conditions, there is no consensus of maturity indices. It is important that maturity indices be established for the different cultivar, growing region, and purpose of harvest. Changes associated with ripening include starch to sugar conversion, which increases sweetness, decreased acidity, increased carotenoids ond/or anthocyanin pigments (depending on cultivar) and aroma volatiles.

**Quality indices**

These include uniformity of shape and size, skin color (depending on cultivar and consumer preference), fiber content, flavor, flesh firmness, and freedom from decay and defects including sunburn, sap burn, skin abrasions, stem-end cavity, hot water injury, chilling injury and insect damage. There are large differences in flavor (sweetness, sourness, aroma) quality and fiber content among cultivars.

Figure 2. Mango fruit

**Harvesting**

Harvesting should be done during a cooler period of the day to reduce field heat. The fruit should be cut with scissors leaving a stem of about 2 cm, that should be cut again later to about 0.5 cm. several harvesting aids are used for mango, especially for vigorous trees; most commonly a half-elliptical basket attached to a long polo fixed with a severing blade or scissor. Fruit should never be allowed to drop on the ground. Fruits are commonly transported to packinghouse in wooden or plastic boxes.

Figure 3. Plastic boxes used for transporting fruits (Dr. Elhadi Yahia).

**Packing**

De-sapping practiced in some countries is very inefficient, and causes several problems including fruit injury, and even decay development. The avoidance of fruit latex exudate in several cultivars is possible by leaving a sufficiently long peduncle (2 cm) and then cutting it back to about 0.5 cm), and also by receiving the mango in water. Mango fruit is commonly packed in a packinghouse. Fruits are commonly received in water tanks; washed at ambient temperature containing chlorine and/or a fungicide and then dried. The fruit are then pre-selected, classified by size or weight and different quality grades. Waxing is done for some cultivars to improve fruit appearance and to decrease water loss, especially for heat-treated fruits. Packaging is commonly done manually in fibreboard boxes of 4.5 to 6 kg capacity.

Figure 4. Fibreboard boxes used for export (Dr. Elhadi Yahia).

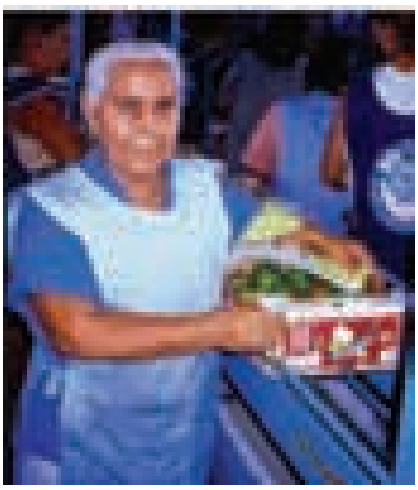

Figure 5. Mango packing in Mexico (Dr. Elhadi Yahia).

**Optimum storage and transport conditions**
Optimum temperature is 13°C for mature-green mangoes, and 10°C for partially-ripe and ripe mangoes, and optimum relative humidity is 90-95%. Pre-cooling, using forced air cooling is the ideal method for mango fruit, especially after heat-treatments.

**Controlled atmospheres (CA)**
CA is not used during mango storage, but it is used during marine transport in some countries. Optimum CA conditions are 3-5% $O_2$ and 5-8% $C0_2$, depending on cultivar, maturity stage, postharvest treatments, and desired postharvest life. CA delays ripening and reduces respiration and ethylene production rates. Postharvest life potential at 13°C is 2-4 weeks in air and 3-6 weeks in CA (during transport), depending on cultivar and maturity stage. Exposure of the fruit to concentrations below 2% $O_2$ and/or above 8% $C0_2$ for a prolonged period of time may induce injury including skin discoloration, grayish flesh color, and off –flavor development.

**Ripening**
Exposure of mango fruit with 100 ppm ethylene for 12 to 24 hours at 20 to 22ºC and 90-95% relative humidity results in accelerated and uniform ripening within 5-9 days, depending on cultivar and maturity stage. Carbon dioxide concentration should be kept below 1% in the ripening room.

**Physiological disorders**
Sapburn is dark-brown to black discoloration of mango skin due to chemical and physiological injury from exudates (sap).

Skin abrasions are due to fruit rubbing against rough surfaces or each other resulting in skin discoloration and accelerated water loss.

Mango is susceptible to chilling injury (CI). CI symptoms include uneven ripening, poor color and flavor, surface pitting, grayish scald-like skin discoloration, increased susceptibility to decay, and in severe cases, flesh browning. CI incidence and severity depend on cultivar, ripeness stage (ripen mangoes are less susceptible), temperature, and duration of exposure.

In general, mango fruit is resistant to heat as compared to several other fruits. However, exposure of the fruit to temperatures above 30ºC for longer than 10 days results in uneven ripening, mottled skin and strong flavor. Exceeding the time and/or temperature combinations of heat treatments recommended for decay and/or insect control can promote heat injury, which includes skin scald, blotchy coloration, and uneven ripening.

Internal flesh breakdown (stem-end cavity) and development of internal cavities between seed and peduncle can develop in tree- ripened mangoes.

Jelly-seed (premature ripening) is the disintegration of flesh around seed into a jelly-like mass.

Soft-nose appears as softening of tissue at the apex, where the flesh appears over-ripe and may discolor and become spongy. This disorder may be related to calcium deficiency.

**Postharevst diseases**

Decay is one of the most important causes of postharvest losses, especially in humid climates. Anthracnose is the most serious disease in most mango growing regions. Infection can be in the fruit, but also on blossoms, leaves, twigs and young branches. It is caused by *Colletotrichum gloesporioides* and begins as a latent infection in unripe fruit and develops when the mangoes begin to ripen, especially at high temperature and high relative humidity. In addition to attacks through the wounds, the organism penetrates the fruit through the cuticle and natural opening on the fruit surface. Lesions may remain limited to the skin or may invade and darken the flesh.

Diplodia stem-end rot, caused by *Lasiodiplodia theobromae*, is second in importance to anthracnose and affects mechanically-injured areas on the stem or skin. The fungus grows from the pedicel into a circular black lesion around the pedicel. Infection can be reduced by leaving a stem of about 1-2 cm.

Other diseases that can attack the mango fruit in postharvest include *Rizopus* (*Rizopus oryzae*), scab and sooty mold caused by *Cannodium mangifera*, alternaria rot caused by *Alternaria alternata*, and black mold caused by *Aspergillus niger*.

Decay Control measures are accomplished with an adequate preharvest and postharvest integrated program. Adequate harvesting method, careful handling of the fruit, avoidance of mechanical injury, rapid cooling, maintenance of optimum (low) temperature in storage and during shipping, and maintenance of hygienic conditions are essential for decay control. In postharvest, washing water usually contain about 100 ppm sodium hypochlorite, and may also contain a fungicide depending on the extent of the problem. Postharvest hot water treatments are used for decay control, and consist in dipping the fruit in water at 48 to 55°C for 3 to 15 minutes, depending on the incidence of decay, cultivar, and fruit size. Higher temperatures are applied for shorter periods of time. Hot water is more effective for anthracnose than for stem-end rot. Fruit should be cooled down in water at ambient temperature immediately after the heat treatment.

**Insects**

Mango is susceptible to infestation by several insects, including mango weevil, mango seed borer, and several fruit flies. Measures for insect control include preharvest and postharvest programs. Pre-harvest programs include cultural practices, traps, chemical treatments, use of sterilized insects, etc. Postharvest chemical control has been achieved using organophosphates and hydrolyzed albumen. Postharvest hot water dipping treatment at 46.1°C for 65, 75 or 90 minutes is used in several mango production regions as a quarantine treatment against some fruit flies. Fruits are cooled down with water at ambient temperature immediately after the heat treatment, and then pre-cooled again with forced air cooling after packing.

**Recommendations**

1. Apply an integrated pre-harvest program for fertilization, irrigation, and for the control of diseases and insects.
2. Refer to regulations in different countries regarding the use of chemicals.
3. Develop and use adequate maturity indices for different cultivars in different regions.
4. To reduce the problem of latex exudates, harvest in mid-morning, avoid picking immature fruits, and avoid picking right after the rain.
5. Harvested fruit in the field should be maintained in the shade.
6. Careful handling to minimize mechanical injuries.
7. Postharvest hot water dipping treatment for 3-15 minutes at 48-55 °C for decay control (depending on incidence of decay, cultivar, fruit size).
8. Postharvest hot water dipping treatment for 65, 75 or 90 minutes at 46.1 °C for insect control (depending on fruit size).
9. Postharvest fungicide (imazalil or thiabendazole) treatment, alone or in combination with hot water treatment, for decay control.
10. Pre-cool and maintain fruit at low (optimum) temperature.

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# Nectarines (*Prunus persica var. nectarina*)

**Quality characteristics**
High quality nectarines should have high soluble solids content (SSC), and the relation between SSC and titratable acidity is very important. Fruit firmness is important for quality, and fruit with 9 to 13.5 Newton of flesh firmness are considered ready-to-eat, although fruit with higher firmness are highly accepted by consumers.

**Maturity indices**
In several growing regions harvest date is determined by skin ground color which changes from green to yellow in most cultivars, where color chip guides are used in some regions to determine maturity of each cultivar except for white-flesh cultivars. Fruit firmness (measured with a penetrometer with an 8-mm tip) is also used in some regions as an indicator of maturity, recommended for cultivars where skin ground color is masked by full red color development before maturation.

Nectarine harvesting

**Harvesting and packaging**

Nectarines are commonly hand-picked into bags, baskets or totes and then dumped into bins on trailers between tree rows in the orchard. If fruit are picked into totes, these are usually placed directly inside bins. Most of the yellow-flesh nectarines are packed into 2-layer (tray) boxes, and small size, yellow-flesh nectarines are generally volume-fill packed, while most of the white-flesh and "tree ripe" nectarines are packed into 1-layer (tray) boxes.

**Storage and transport conditions**

Nectarines should be pre-cooled immediately after harvest, commonly done in field bins using forced-air cooling or more adequately hydro-cooling. Fruit can be pre-cooled to 5 to 10°C if packing is to be done the next day, and to near 0°C if packing is delayed. Fast pre-cooling (within 8 hours) and maintaining fruit at temperature near 0°C is important, especially for cultivars susceptible to internal browning.

Storage and long-distance shipments should be done at -1 to 0°C with minimum fluctuations and 90 to 95% RH. Modified and controlled atmospheres (using 1-2% $O_2$ + 3-5% $CO_2$), especially during shipment can retain fruit firmness, color changes and decreases internal browning. An atmosphere with 10% $O_2$ + 10% $CO_2$ is sometimes used for reduction of internal breakdown during storage and shipments. However, $O_2$ less than 1% and $CO_2$ higher than 20% can cause the development of off-flavors and browning.

**Physiological disorders**

Some cultivars are susceptible to CI or internal breakdown (IB). CI symptoms develop faster and more intensely at 0°C or below than at 2.2-7.8°C. It is a physiological problem characterized by internal flesh browning, flesh mealiness or leatheriness, flesh bleeding, failure to ripen, and flavor loss. In most cases, the red color development inside the flesh (bleeding) is not an IB symptom, and it does not affect taste. These symptoms develop during ripening after a cold storage period, and thus, are usually detected by consumers. However, there is large variability in susceptibility to IB among cultivars. Some of the treatments that can delay the development of this disorder include ripening of fruit before storage and storage or shipping in 10% $CO_2$ + 10% $O_2$ for some cultivars.

Inking (black staining) is a cosmetic problem affecting only the skin of the fruit, and is characterized by black or brown spots or stripes, that appear generally 24 to 48 hours after harvest.

**Postharvest diseases**

Brown rot (*Monilinia fructicola*) is the most important postharvest disease in nectarines, where infection begins during flowering and fruit rot may occur before harvest but often occur after harvest. Orchard sanitation to minimize infection sources, pre-harvest fungicide application, and fast postharvest cooling are important control strategies.

Gray mold (*Botrytis cinerea*) can cause serious damage during wet spring weather, and can occur during storage if the fruit has been contaminated through wounds resulted during harvest and handling. Reducing mechanical damage and good temperature management are effective control measures.

Rhizopus rot (*Rhizopus stolonifer*) can infest ripe or near-ripe fruit at 20 to 25°C, and therefore pre-cooling and maintaining fruit at lower than 5°C is an effective control.

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# Netted Melons, cantaloupe or muskmelon (*Cucumis melo* L.)

Figure 1. Packaged melons (Dr. E.M. Yahia).

**Quality characteristics**

Good quality melons should have sufficient maturity to insure completion of ripening, sufficient firmness (not soft or wilted), adequate shape and netting characteristic for their type, a stem scar not wet and slippery (wet slip), no sun scald (solar injury), flesh and rind free of decay by fungi or bacteria, and absence of damage. Minimum soluble solids content, depending on the market, is also required.

**Maturity indices**

Some of the maturity indices include stem separation and background rind color. A separation layer, or abscission zone, develops at the point where the stem attaches to the fruit as netted melons begin to ripen. Most netted melons are commercially harvested when half of the stem has separated from the melon, called "½ slip". Abscission zone development often corresponds to a change from green to yellow in rind background color. If picked at proper maturity, netted melons will continue to soften and become more aromatic after harvest, but if harvested prematurely by cutting the stem prior to abscission zone development they may produce little aroma, have low soluble solids content, and do not ripen properly.

Figure 2. Bringing melons from the field to packing.

Figure 3. Packing melons.

**Storage and shipping conditions**
Pre-cooling soon after harvest to a fruit center temperature of 10 to 15°C is essential for melons to delay ripening and retain sugar content. This process can be done by hydro-cooling, forced-air cooling, or top-icing, although hydro-cooling is most adequate. Optimum storage/shipping condition is 2-7°C and 95% RH for about 10-14 days. Controlled atmospheres (3 to 5% $O_2$ and 10 to 20% $CO_2$), especially for transport have some potential for maintaining fruit quality and extending shelf-life. However, maintaining in an atmosphere containing more than 10% $CO_2$ may result in a carbonated taste that is lost during subsequent storage in air. Off-flavors andoff-odors, and impaired ripening may develop if netted melons are maintained at less than 1% $O_2$ or more than 20% $CO_2$.

**Physiological disorders**
Melons are sensitive to chilling, but sensitivity decreases as fruit mature, and the symptoms may appear as pitting, surface decay, and failure to ripen. Full-slip, netted melons may be maintained for 5 to 14 days at 0-2°C, but less mature fruit can be damaged by storage at less than 2°C.

Solar injury causes patchy ground color or "bronzing" and net discoloration, and severely injured tissue becomes sunken or wrinkled. Vein track browning, a darkening of the longitudinal tracts between netted areas, is caused by exposure to sun or high temperature at harvest. Netted melons are easily injured, and therefore it is important to avoid mechanical injury during handling and to maintain fruit under optimum storage and shipping conditions.

Figure 4. Melon package.

Figure 5. Polyethylene liners are used to reduce water loss.

Figure 6. Ethylene absorbent in melons in packaged melons.

**Postharvest diseases**

*Fusarium* rot is the most common disease in cantaloupes, and symptoms vary depending on *Fusarium* species, but large fissures and enlarged or thickened, dark-tan net at the lesion site are common. Other less common diseases include black rot caused by (*Didymella bryoniae* or *Phomopsis cucurbitae*); *Rhizopus* soft rot caused by *Rhizopus stolonifer*; bacterial brown spot caused by *Erwinia ananas*; bacterial soft rot caused by *Erwinia carotovora*; and *Alternaria* caused by *Alternaria alternata*. A very effective decay control measure includes fungicide application in a hot-water dip for 1 min at 57°C.

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# Peaches (*Prunus persica*)

Figure 1. Peach fruit

Peach fruit development follows a double sigmoid curve. It is a drupe, endocarp is hard forming the stone, mesocarp is fleshy (soft or juicy) and the exocarp is a thin outer flesh. Fruit is characterized by a hairy layer cover; no waxy cover is present, and is perishable and sensitive to mechanical injuries.

Peach fruit is climacteric and the increase in ethylene production is associated with the increase in respiration rate at ripening. Ripening is characterized with color appearance of the cultivar, decrease in firmness, increase of sugars and the development of the characteristic flavor.

**Harvesting date and ripening and quality characteristics**
The ripening stage at harvest is the most important limiting factor for storage ability and final quality level. Immature fruits will be sensitive to wilting and mechanical injuries and will have poor quality at ripening, and advanced ripe fruits will be soft and unsuitable for storage. External color, firmness and total soluble solids content of fruits are used for determining harvesting time. Quality characters include fruit size, color, absence of physiological disorders, diseases, in addition to internal fruit quality such as sugars and acids contents.

Fruit growth is 90 – 130 days from full bloom depending on cultivar. Fruits should be picked at full physiological maturity to continue the ripening process after harvesting. Internal fruit changes occurring during ripening include fruit softening, natural color characteristic of each cultivar, increase in total soluble solids content (TSS) to 9-14%, increase in sugars to 6-10% and a decrease in total acidity to less than 1%. Fruits should be hand picked by bulling fruits out with twisting and avoiding pressure on fruits to avoid injury. It is preferred to harvest fruits early in the morning to reduce filed heat, to be then packed in the field or transported to a packing house.

**Packing and packaging**

1. Removing dust or sands by cleaning brushes.
2. Sorting and grading according to quality standard.
3. Grading according to size.
4. Packing according to purpose (1-2 layers).
5. Pre-cooling can be done by hydro-cooling, room cooling, forced-air cooling to remove field heat. In case of using hydro-cooling, pre-cooling can be done before sorting and grading.
6. Transport to cold rooms for storage or to market.

Figure 2. Peach fruit.

Figure 3. Peaches in Egypt.

**Optimum storage and shipping conditions**

- Temperature: $0^oC$.
- Relative humidity: 90 – 95%.
- Storage period: 3-4 weeks at optimal conditions.
- Pre-cooling: necessary to get red of field heat and to prolong storage period, cold water (hydro-cooling) is the optimum for peach pre-cooling.
- Storage for a short period is possible along with apples, apricot, figs, plums, carrots and other crops that are stored at $0^oC$ and 90-95% relative humidity.

**Physiological disorders**

- Chilling injury: occurs at below 0°C due to tissues breakdown.
- Fruit aging: occurs after long storage period where fruits loose flavor and normal color.

**Diseases**

Brown rot, caused by *Monilinia fructicola* is the most important disease-causing organism in peaches, and can be controlled by fast pre-cooling and treating fruits by hot water at 55°C for 2-3 minutes. *Rhizobus* rot is also important and can be controlled by fast pre-cooling.

Figure 4. Brown rot on peaches

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# Pomegranate (*Punica granatum* L.)

Pomegranate culture is widespread in different regions in the world, in particular in the Middle East, North Africa and Southern Europe, and in fact it is increasing in several countries including the USA after pomegranates has been found to contain high amounts of antioxidants.

**Quality characteristics and ripening indices**

Quality characteristics include freedom from cracking (splitting) and other mechanical injuries, and complete color (attractive skin) depending on cultivar. Ripening indices include suitable size, adequate color of exocarp and internal kernels, and adequate relation of total soluble solids to acidity. Total soluble solids of 17% or more and 0.25% tannins are desirable, depending on type of variety.

Figure 1. Pomegranate harvesting in Egypt (Source: Dr. Hecham Allam).

**Harvesting and packing**

Fruits harvest should be done when they reach suitable ripening stage, using pruning shears. Fruits are then transferred to packing houses for cleaning, sorting to exclude cracked and diseased fruits, and then sized and packing in carton or wooden packages.


Figure 2. Pomegranate packages
(Source: Dr. Hecham Allam)

**Storage conditions**

- Temperature: 5-7°C
- Relative humidity: 90-95%
- It is possible to store pomegranate fruit for up to 2-3 months depending on fruit condition and when pre-cooling is applied.
- For a short period pomegranate fruits can be stored for 2-4 weeks with other crops such as pepper, cucumber, orange, olive, okra, watermelon, when stored at 5-10°C and 90-95% RH. For longer periods they can be stored with oranges at 5°C and 90-95 RH.

**Physiological disorders**

- Chilling injury: occurs when fruit is maintained at less than 5°C. Injury appears as deep scars (notches or stains), which spread on fruit surface, then browning (coloring) of internal white tissues (endocarp) which holds the kernels.
- Internal breakdown of fruit is represented by small kernels not attaining red color associated with abnormal smell. The cause of this disorder is not known.
- Sunburn: this disorder occurs at fruit-tree junction.
- Cracking: This disorder occurs while fruits are on the tree and irregular irrigation may be the reason**.**

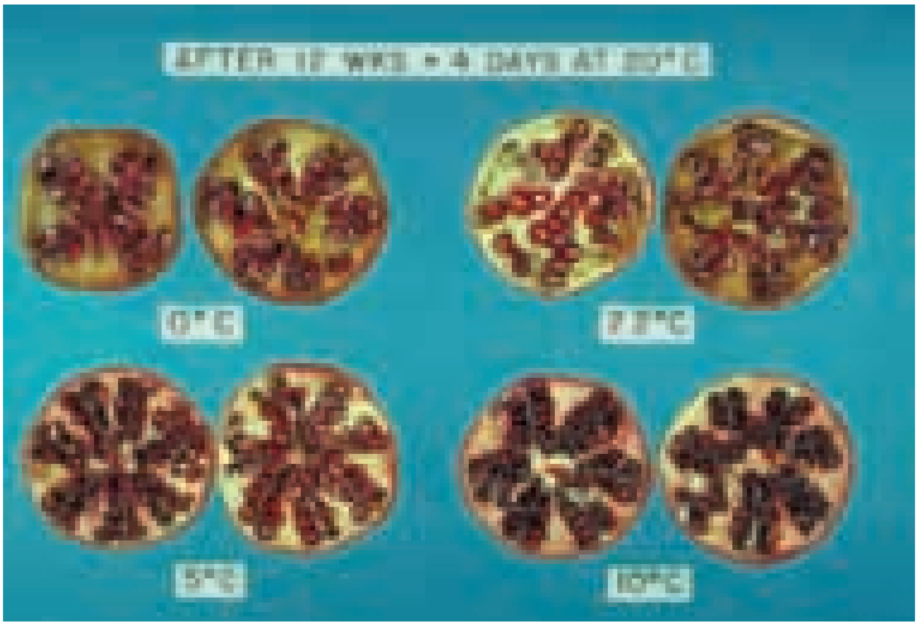


Figure 3. Pomegranate response to different temperatures
(Source: Dr. A.A. Kader).

**Important diseases**

- Gray rot: this disease starts at the calyx which leads to turning fruit skin to brown color with leathery texture.
- *Alternaria* rot: this disease leads to slight coloring on fruit skin while kernels appear as a black mass. The disease can not be recognized from outside the fruit.
- *Penecillium* rot: appears as watery scars or stains on fruit skin associated with the growth of green and blue spores.

**To control pomegranate diseases:**

- Pre-cooling fruits to temperature close to optimum storage and shipping temperature.
- Remove cracked fruits.
- Avoid mechanical injuries.
- Use suitable fungicides.

Figure 4. Pomegranate chilling injury symptoms.

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# Plum (*Prunus salicina*)

Figure 1. Plum fruits

**Quality characteristics**

Some of the important quality components for plums include soluble solids contents (SSC), titratable acidity (TA), SSC:TA, and phenolic content (causing fruit astringency). Plums with about 1 kg-force flesh firmness, using 8-mm tip penetrometer, are considered ready-to-eat.

**Maturity and harvesting indices**

Harvesting date for some plum cultivars is determined by skin color changes, using a color chip guide. Flesh firmness, measured with an 8-mm tip penetrometer, can also be used, especially for cultivars where skin ground color is masked by full red or dark color development before maturation. Plums for fresh market are hand harvested.

**Packing and packaging**

Plums are commonly collected in bags, and then dumped in bins that are moved on trailers between tree rows in the orchard.  At the packinghouse, plums are commonly washed, sorting is done to eliminate fruit with visual defects and sometimes to divert fruit of high surface color to a high-quality pack.  Fruit sizing is done either by weight or dimension, and fruit are commonly packed in 12 kg volume-filled containers.

**Storage and transport**

Plums should be pre-cooled in field bins prior to packing to near 0°C using forced-air cooling, hydro-cooling, or room-cooling. Optimum storage and transport conditions are -1.1 to 0°C at 90 to 95% relative humidity, and postharvest life varies among cultivars and it is strongly affected by temperature management. Storage life of ‘Blackamber,’ ‘Fortune’ and ‘Angeleno’ plums at 0°C can reach up to 5 weeks. Internal breakdown (IB) development is delayed in susceptible cultivars at -1.1°C, but freezing damage can be a problem in case that SSC is low. Modified and controlled atmospheres which can be used during marine transport, can help in retaining fruit firmness, in delaying the changes in ground color, and in reducing decay incidence.

**Physiological disorders**

Most plum cultivars are susceptible to chilling injury (CI) when stored at 5°C. ‘Show Time,’ ‘Friar,’ and ‘Howard Sun’ plums develop CI symptoms within 4 weeks, even when stored at 0°C. In all plum cultivars, a much longer storage life is achieved when stored at 0°C than at 5°C. CI is expressed as flesh translucency associated with flesh browning. Late plum cultivars also develop lack of juiciness in addition to these symptoms. It normally appears after placing fruit at ripening temperatures following cold storage at 2-8°C.

**Postharvest diseases**

As it is the case in other stone fruits, brown rot (caused by *Monilia fructicola*) is the most important postharvest disease of plums. Infection begins during flowering, and fruit rot may occur before harvest, but often after harvest. Orchard sanitation to minimize infection sources, pre-harvest fungicide application and fast pre-cooling after harvest are effective control measures. Fruit cracking makes late season cultivars more prone to decay. Postharvest fungicide treatments may be used to limit decay.

Gray mold (caused by *Botrytis cinerea*) can be serious during wet, spring weather, and it can occur during storage if fruit have been contaminated through harvest and handling wounds. Avoiding mechanical injuries, effective temperature management and postharvest fungicide treatments are effective control measures.

*Rhizopus* rot (caused by *Rhizopus stolonifer*) can occur in ripe or near-ripe fruits kept at 20 to 25°C, but pre-cooling fruit and storing at below 5°C is effective in controlling it.

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# Strawberry (*Fragaria* x *ananassa*)

Figure 1. Strawberry fruits.

Strawberry is a non climacteric fruit and one of the most perishables. It is harvested at full ripening therefore it becomes very sensitive handling. Due to its high respiration rate and sensitivity to handling, strawberry is characterized by very short postharvest life, and therefore it needs special care at harvest and handling in addition to a fast and efficient cooling.

**Maturation and ripening**

Strawberry fruit color is green at fruit set turns to white then coloring starts as purple and then red. Coloring occurs gradually associated with an increase in fruit size and a decrease in firmness while increasing in total soluble solids including sugars. The duration from flower open to fruit ripening is about one month depending on predominant temperature. Strawberry fruit quality does not improve after picking from the plant; they do not continue the process of ripening and the increase in sugar content after harvest.

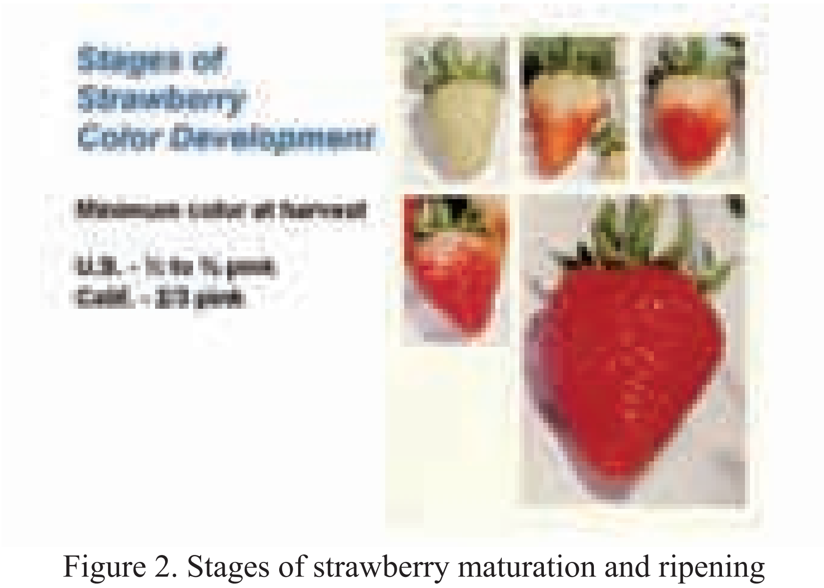


Figure 2. Stages of strawberry maturation and ripening
(Source: Dr. A.A. Kader).

**Picking and packing**

Strawberry fruit is commonly picked and packed in the field directly in consumer packages. Strawberry fruits should be carefully picked by holding fruit peduncle between fingers while the fruit is inside the hand-palm, then fruit is twisted around to separate fruit with 0.5-1.0 cm of the peduncle and then placed directly in a consumer package; such a method would keep the green calyx which gives fruit a good looking. It is important to avoid pulling fruits from the plant so not to loose any part from the green calyx or loose a part from the fruit itself. Packing boxes should be clean, smooth and not too deep, with dimensions of about 40 x 70 cm and 7 cm height. No sharp edges should be allowed to avoid mechanical damages to fruits. It is preferred to have a 1 cm spongy base layer to absorb shocks when arranging fruits inside boxes.

Picking, sorting, grading and packing fruits in the field reduce and minimize touching and handling, and thus maintain quality and prolong marketing period. Field packing reduces deterioration and also reduces the time between harvest and pre-cooling. Special carts are used for this target. Carts can move between strawberry planting rows, packing boxes with plastic baskets are put on the top of such carts. Fruits are inspected by quality inspectors then covered and placed in carton boxes to be then transferred to pre-cooling as soon as possible.

In some places strawberries are packed in a packinghouse, although strawberries should ideally should be packed in the field. Trained workers (usually women) at packing houses start to sort fruits in wooden trays (field packs) to exclude mechanically injured and diseased fruits in addition to mis-shaped or malformed fruits, fruits with sunburns, over ripe ones, decalyxed ones, small, injured and green fruits. Workers then clean fruits by rubbing with dry soft brush, and cutting fruit peduncle to a suitable length (0.5-1.0 cm). Fruits are then placed in plastic packs with cover which has holes to allow ventilation. Dimensions of carton packs are commonly 60 x 40 cm. These cartons will include plastic packs with a capacity of 250 or 400 grams of fruits and total weight per carton pack of about 2 kg. Each 4 carton packs would be tied together to be sent to quick cooling.

**Pre-cooling (Fast cooling)**

Fast pre-cooling (preferably no later than 3 hours after harvest) is very important to reduce deterioration in strawberries. Optimum pre-cooling method for strawberry is forced-air cooling. The objective of quick cooling is the rapid removal of field heat after crop harvest and to lower fruit temperature to a level equal or close to the storage or shipping temperature, in order to reduce biochemical processes in addition of reducing water loss as well as fungal activity.

**Storage and shipping conditions**

Pallets of fruits are transferred after quick cooling to cold room. The pallets can be individually covered with large plastic bag fixed at wooden bases by wrapping ribbons, and then carbon dioxide gas can be injected into small holes at the top of the plastic bags at the rate of 12-15%, then the hole is closely tied after gas injection. Pallets are then transferred to refrigerated containers. This method of using modified atmosphere can help controlling decay, reduction of respiration rate, and can prolong marketing period and secure fruit transport to distant markets.

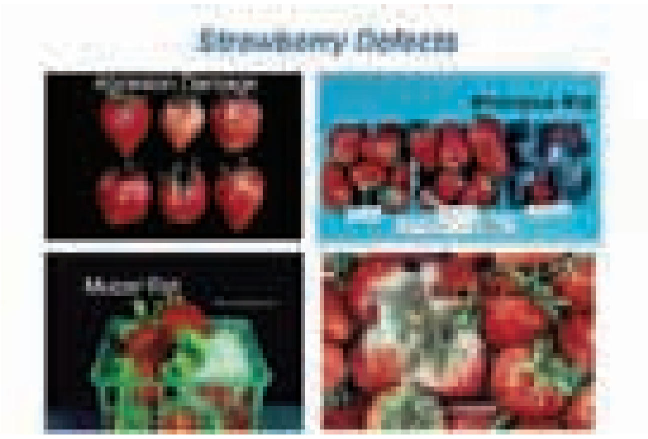


Figure 3. Some defects and diseases on strawberry
(Source: Dr. A.A. Kader).

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# Watermelon (*Citrullus lanatus*)

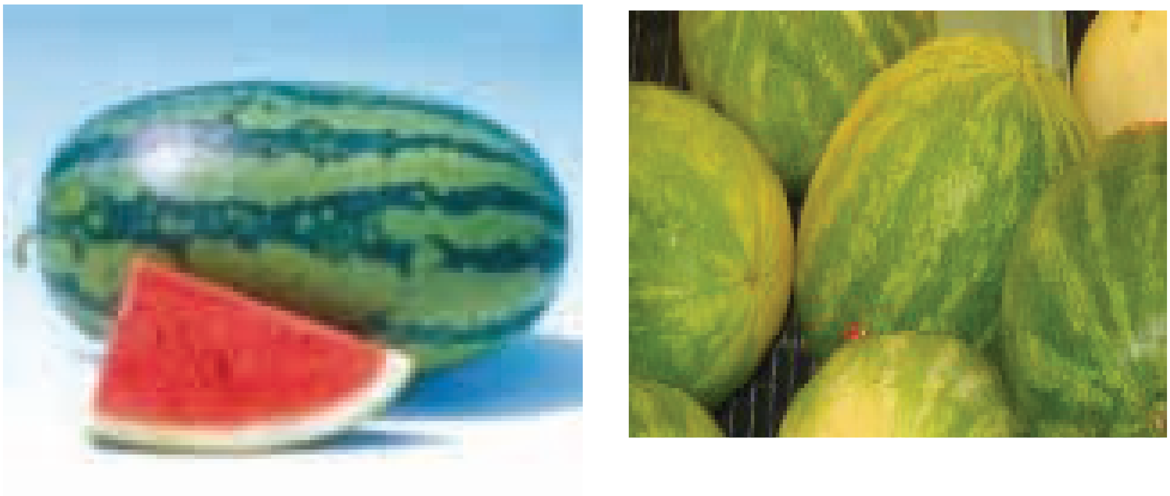

Figure 1. Watermelon fruit.

**Quality characteristics**

High quality watermelons should be well formed uniform in shape depending on cultivar and type, with a waxy, bright appearance, and the rind should be free of scars, sunburn, and abrasions with no bruising or other physical injury, and free from decay.

**Maturity indices**

Maturity of watermelons is determined by ground spot changes from white to pale yellow, tendrils nearest the fruit may turn brown and dry, and the fruit surface may become irregular and dull rather than bright or glossy. When the fruit is thumped or rapped with the knuckles, mature fruit will sound dull or hollow and immature fruit will give off a metallic ringing sound. However, the most reliable method of determining maturity is to look for the changes described above, in addition of cutting some fruit in random. Soluble solids content is also used to determine maturity.

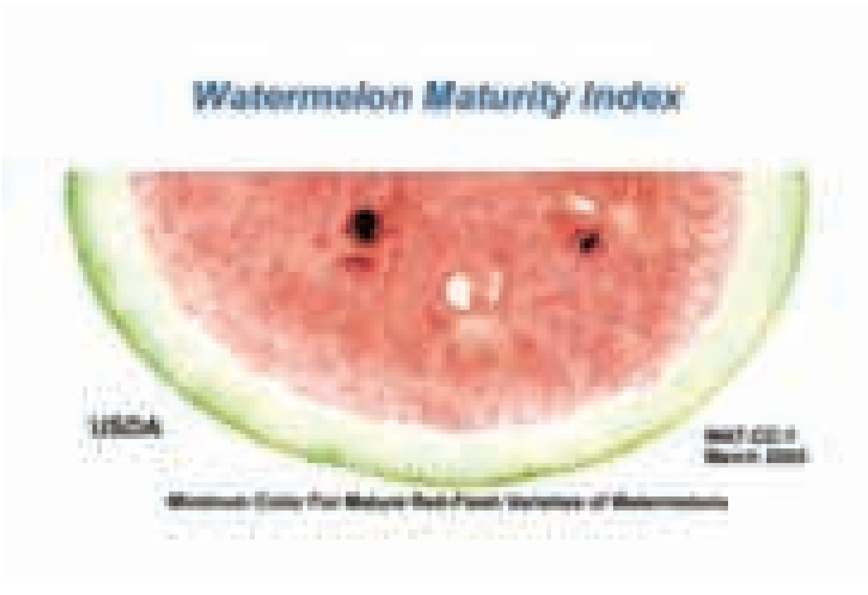


Figure 2. Maturity index (Source: Dr. A.A. Kader).

**Packaging**
Watermelons are commonly shipped in bulk, placed on corrugated bins with a capacity of approximately 400 kg, or packed into cartons containing from 3 to 6 watermelons depending on fruit size, and these cartons should have specially designed inserts to help support the weight of the fruit.

**Storage and transport**
Watermelons are not commonly pre-cooled and sometimes are shipped in unrefrigerated trucks, depending on distance. If pre-cooling is needed, forced-air cooling is the optimum method, although room cooling can be implemented, however, good air circulation between palletized boxes is essential. Optimum storage conditions are 10-15°C and 90% RH for a maximum of about 2-3 weeks.

**Physiological disorders**
Watermelons is sensitive to chilling when exposed to temperatures below about 10°C, and lower temperatures will hasten the onset of injury. Chilling symptoms include brown-staining of the rind, surface pitting, deterioration of flavor, fading of flesh color, and increased incidence of decay when returned to room temperatures. Conditioning fruit at 30°C for about 4 days prior to cooling induces some tolerance to chilling temperatures, but it does not completely alleviate the problem.

Watermelons produce low concentration of ethylene (0.1 to 1.0 μL/kg/h at 20°C), but fruit is extremely sensitive to ethylene where as little as 5 ppm causes softening, rind thinning, flesh color fading, and over-ripeness. Therefore it is important to avoid exposure to ethylene during storage or transport.

"Hollowheart" is a pre-harvest disorder with serious postharvest consequences, and the most effective way of eliminating it is to utilize production practices that prevent its occurrence.

**Postharvest diseases**
Several pathogens can cause postharvest decay in watermelon. Postharvest rots caused by *Fusarium* spp. and *Phytophthora capsici* are of concern because control measures for these fungi in the field often are inadequate. With good disease control in the field, anthracnose (*Colletotrichum orbiculare*) and black rot (*Didymella bryoniae*) rarely develop on watermelon. In production areas with high relative humidity and temperature, an extensive list of rind lesions, stem-end or blossom-end rots, and surface lesions may be caused by *Erwinia* or an assortment of fungi.

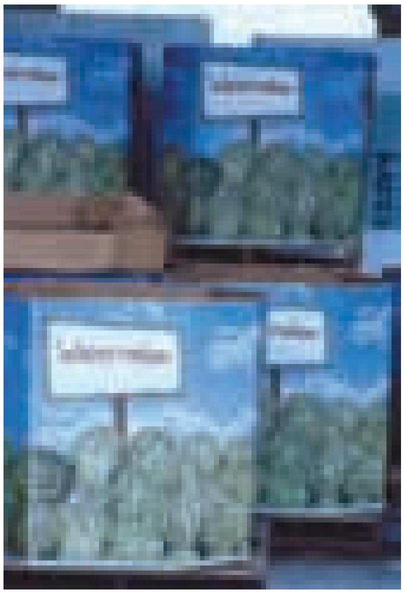

Figure 3. A package used for watermelon (Source: Dr. Elhadi Yahia).

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# CHAPTER THREE

# POSTHARVEST HANDLING OF SOME VEGETABLES

# Carrot (*Daucus carata* L.)

Figure 1. Carrots

**Quality characteristics and criteria**

In general, high quality carrots should be:

- Firm (not flacid or limp).
- Straight with a uniform taper from ‘shoulder' to ‘tip'
- Bright orange.
- There should be little residual "hairiness" from lateral roots.
- No "green shoulders" or "green core" from exposure to sunlight during the growth phase.
- Sweet with no bitterness from terpenoid compounds.
- High moisture content and high reducing sugars are desirable for fresh consumption.
- No cracking or sprouting.

**Maturity and harvesting indices**

- Harvest of carrots is based on several criteria depending on the market outlet or sales endpoint.
- For fresh market, most carrots are harvested partially mature, when the roots are about 1.8 cm or larger in diameter at the upper end.
- Late harvesting may improve storability by reducing decay during extended storage.
- For fresh-cut processing, carrots are harvested immature to insure they are tender and sweet.
- Typically carrots are harvested at an immature state when the roots have achieved sufficient size to fill in the tip and develop a uniform taper.
- Length may be used as a maturity index for harvest timing of ‘cut and peel' carrots to achieve a desired processing efficiency.

**Grading and packaging**

- Carrots can be harvested either bunched or top trimmed; top trimmed is the dominant method.
- The common grades for bunched carrots are No. 1 and commercial grade. For topped carrots, the grades are extra No. 1, U.S. No. 1, No. 1 Jumbo, and No. 2.

- Topped carrots are typically packed in 0.5 to 2.25 kg consumer bags that are grouped in 11 or 22 to 22.7 kg cartons or master poly bags.
- Bunched carrots are packed loosely in 12 kg cartons.

**Cooling, storage and shipping**

- Prompt washing and hydro-cooling to less than 5 °C is essential to maintain carrot freshness and crispness.
- Typically, carrots pass through several wash and flume steps that remove field heat and are then hydrocooled in chlorinated water before packing.
- Storage temperature at 0 to 1 °C is essential to minimize decay and sprouting during storage.
- High RH is required to prevent desiccation and loss of crispness.
- The recommended conditions for commercial storage are 0 °C with 98 to 100% RH. Under this condition, mature topped carrots can be stored for 7 to 9 months.
- However, commercial storage and distribution condition rarely achieve the optimum storage conditions and topped carrots can be stored for 5 to 6 months at 0°C to 5°C with 90 to 95% RH. Common "Cello-pack" carrots are typically immature and may be stored successfully for 2 to 3 weeks at 3 to 5 °C. Bunched carrots are highly perishable due to the presence of leaves and can be maintained for only 8 to 12 days. Bunched carrots are typically shipped and stored with shaved or flake-ice.
- Carrots should be displayed loosely on a shelf with mist or in polyethylene consumer packages.

**Physical and physiological disorders**

- Bruising,
- Shatter-cracks,
- Longitudinal cracking,
- Tip-breakage, are all signs of excessively rough handling,
- Nantes-type carrots are particularly susceptible to mechanical damage,
- The severity of shatter-cracking is partially related to varietal background,
- Wilting, shriveling, and rubberiness are signs of moisture loss,
- Sprouting may occur on topped carrots if the storage temperature is too high,
- Bitterness can develop in storage due to the accumulation of isocoumarin, caused by disease or exposure to ethylene. Harsh flavor may be caused by the high terpenoid content, generally from pre-harvest water stress,
- Surface browning or oxidative discoloration often develops during storage, especially on carrots harvested immature.

**Postharvest pathology**

The most important storage decays are:

- Bacteria soft rot (induced by *Pectobacterium carotovora* or *Pseudomonas marginalis*),
- Gray mold rot (*Botrytis cinerea*),
- Rhizopus soft rot (*Rhizopus spp*.),
- Watery soft rot (*Sclerotinia sclerotiorum*), and
- Sour rot (*Geotrichum candidum*).
- Ozone is fungistatic against *Botrytis* and *Sclerotinia*, but tissue damage and color loss occurs after treatment.
- Good sanitation during packing and storing 0°C are important to minimize postharvest diseases.

## Fresh-cut

- Carrots are commonly used as fresh-cut products such as “baby carrots,” carrot coins, shreds, and sticks.
- Carrots directed or consigned to fresh-cut processing are typically harvested at an immature stage for optimal texture and taste.
- Fresh-cut carrots can have a shelf-life of 3 to 4 weeks at 0°C and 2 to 3 weeks at 3 to 5 ºC.
- “White blush” is a potential problem for processors and shippers of fresh-cut carrots, where a superficial whiteness is caused by dehydration of the cut surface. Low temperature and the presence of residual surface moisture significantly delays development of this disorder.

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# Cucumbers (*Cucumis sativus* L)

Figure 1. Cucumber

Cucumber is an important vegetable crop that can be cultivated in the field or in greenhouses. It is a member of *Cucurbitaceae* family. Fruit curve is simple (sigmoid), and fruit has low specific surface to weight, sensitive to water loss. Mechanical damage is serious in cucumber leading to increasing water loss and diseases. Cucumber fruit is non-climacteric, and sensitive to chilling injury.

**Quality characteristics and maturity indices**
Suitable size is an important harvesting index. Quality characteristics include freedom from misshaped (malformed) fruits, and from diseases and physiological disorders.

Figure 2. Packing cucumbers.

**Harvest and fruit preparation**

- Cucumber fruits are harvested immature and at different stages depending on purpose, where they are picked small for pickling and at other stages for other consumption purposes. Delaying harvest should be avoided where fruits loose their marketing characteristics.
- Harvest is made by shears or by hand. Fruits can be packed in marketing packs in the field or they can be transported to packinghouses where the following processes can be made:
  - Washing with water (cold water can be used to remove field heat) with the addition of chlorine and/or fungicides.
  - Fruits dryness to remove excessive water or moisture.
  - Sorting to exclude damaged fruits.
  - Sizing.
  - Packing in carton bags by hand or mass.
  - Pre-cooling, which can also be done before packing.

**Storage and shipping conditions**

Optimum storage and shipping conditions are 7 – 10 $^{o}$C and 95% relative humidity and storage duration is about 2 weeks.

**Mixed storage with other crops**

Cucumber fruits are not commonly stored for long duration, but they can be stored for short periods with eggplant, watermelon, red tomato, olive and orange.

Figure 3. The effect of low, chilling temperatures on cucumber (Source: Dr. Adel Kader).

Figure 4. *Fusarium* on cucumber (Source: Dr. Adel Kader).

**Physiological disorders**

Wilting: Occurs due to increased water loss where fruits would turn soft and shriveled. This can be avoided by storage at high relative humidity (95%) or fruit waxing or wrapping and keeping in plastic bags with holes.

Cold injury: Cucumber fruits are sensitive to low temperature and injured at less than 7$^{o}$C. Symptoms appear as water stains dark color on the fruit surface, acting as possible entry for disease.

Yellowing: Is a sign of aging and loss of quality, where fruits may become unmarketable. Yellowing is promoted by high temperature and/or ethylene. To reduce yellowing it is recommended to avoid high temperature and also avoid mixing cucumber fruits with ethylene producing-crops such as banana, apple, pear and tomato.

## Diseases

Anthracnose appears as small stain higher in the peel with green color turning to deep scars. This disease appears after days of infection, sometimes symptoms are delayed despite of infection. Other important diseases include soft bacterial rot and *Rhizobus* rot. Storage diseases can be reduced by holding at 10°C and reducing mechanical injuries.

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# Eggplant (*Solanum melongena* L.)

Figure 1. Egg plant

Eggplants may be oval, round, long or pear shaped; the skin is smooth and shiny, and color may be black and purple, yellow, white or striped.

Eggplant is a non-climacteric fruit with ethylene production ranging from 0.1 to 0.7 $\mu L\ kg^{-1}\ h^{-1}$ at 12.5°C, and has a moderate to high sensitivity to exogenous ethylene. Calyx abscission and increased deterioration, particularly browning, may be a problem if eggplants are exposed to more than 1 ppm ethylene during distribution and short-term storage.

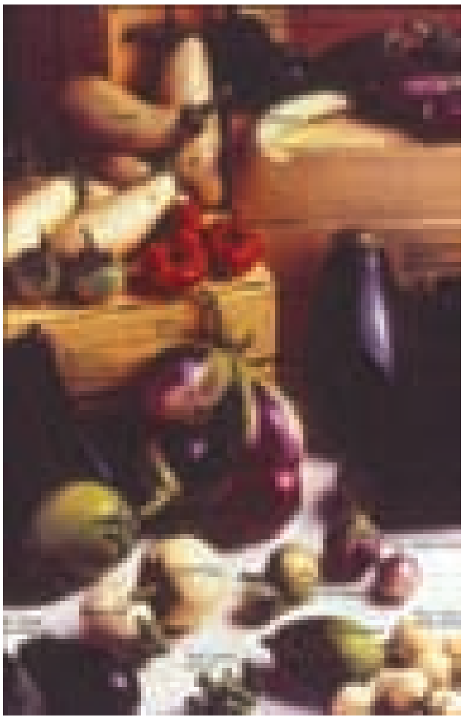

Figure 2. Different types of egg plants

**Quality characteristics**
High quality eggplant should be of uniform size and shape, with a fresh green calyx, free from growth or handling defects and decay. Water loss is important quality deterioration factor, and visible signs are reduction of surface sheen, skin wrinkling, spongy flesh, and browning of the calyx.

**Maturity indices and harvesting**
Eggplant fruits are harvested at a range of developmental stages, depending on the tye of use. Time from flowering to harvest can be from 10 to 40 days. Generally fruits are harvested immature before seeds begin to significantly enlarge and harden. Firmness and external glossiness are also indicators of a pre-maturity condition. Eggplant fruits become pithy and bitter as they reach an over mature condition.

Harvesting is done manually by cutting the calyx-stem from the plant rather than tearing it. Cotton gloves are often used to protect the fruit. Bruising and compression injury is very common when attention to careful harvest and handling practices are not followed.

**Packing**
Packages are commonly one-piece, waxed fiberboard boxes or wire-bound crates, 0.39 $m^3$ containing 15 kg, and fruit are sometimes individually wrapped with paper. Eggplant cannot withstand stacking in bulk containers. Moistened paper or waxed cartons are often used to reduce water loss.

**Storage and transport conditions**
Fast pre-cooling to 10°C immediately after harvest is important to retard discoloration, weight loss, drying of calyx, and decay. Hydro-cooling and forced-air cooling are the most effective, but room-cooling is the commonly used method. Eggplants should not be held in contact with ice.

Fruit should be stored or transported at 10 to 12°C and 90-95% RH. Eggplant can be stored for less than 14 days as visual and sensory qualities deteriorate rapidly, and decay is likely to increase after storage for more than 2 weeks, especially after removal to typical retail conditions. Short-term storage or transit temperatures below this range are often used to reduce weight loss, but can cause chilling injury after transfer to retail conditions.

Wrapping eggplants with adequate plastic films can create a modified atmosphere and reduces weight loss and maintains firmness, due to increasing high RH, especially in Japanese eggplant types, which have a high transpiration rate.

**Physiological disorders**
Eggplants are sensitive to CI after storage for 6 to 8 days at 5°C, that can show symptoms such as surface pitting and scald. Scald refers to brown spots or areas that are first flush with the surface, but may become sunken with time. Browning of the flesh and seeds almost invariably followed by decay caused by *Alternaria* sp. CI symptoms can be reduced by storage in polyethylene bags or polymeric film overwraps, however, increased decay from *Botrytis* is a potential risk.

**Table 1**. Days to visible chilling symptoms at different temperatures in 3 different types of eggplants.

| Temperature | American | Japanese | Chinese |
|---|---|---|---|
| 0ºC | 1-2 | 2-3 | |
| 2.5ºC | 4-5 | 5-6 | 5-6 |
| 5ºC | 6-7 | 8-9 | 10-12 |
| 7.5ºC | 12 | 12-14 | 15-16 |

**Postharvest diseases**

Postharvest diseases often occur in combination with chilling stress. Common fungal pathogens are *Alternaria* (black mold rot), *Botrytis* (gray mold rot), *Rhizopus* (hairy rot), *Phomopsis* Rot, and *Phytophtora* (soft rot).

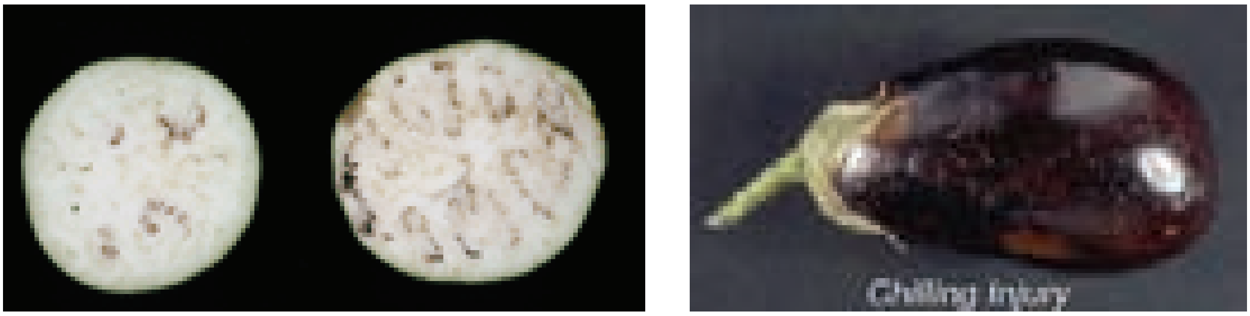


Figure 3. External and internal chilling injury symptoms on eggplant (Source: U.C. Davis).

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# Garlic (*Allium sativum* L.)

Figure 1. Garlic bulbs

Garlic is characterized by low respiration rate and weight loss particularly if thermal curing is applied, which is important in the formation and dryness of external peel of bulbs toward the narrow neck to limit water loss and diseases infestation. Mechanical injuries as well as root growth, germination, fungal infection and dry weight loss are considered as important factors in garlic deterioration.

**Physiological characteristics**
Respiration rat (less than 5 mg $CO_2$/kg/hour) and ethylene production (less than 0.1 µL/kg/hour) of garlic are very low, particularly after thermal curing application. Water content is low about 60%.

**Quality characteristics and maturity indices**
Hard, well-formed bulbs with firm peel are important characteristics of quality in addition to uniformity in size (not-doubled), freedom from fungal diseases, not germinated, not sprouted and with no wounds. Garlic bulbs are harvested after full ripening, and wilting or leaning of leaves are used as an indicator.

Figure 2. Mature garlic

**Causes of loss and deterioration**

1. Mechanical injuries, especially during harvest.
2. Sprouting, particularly after storage for 3 months or more.
3. Dry weight loss.
4. Disease infestation.

**Harvesting and packing**

Garlic bubs are harvested manually or by machines at full maturation, which can be detected from dryness of the vegetative growth, leaning of leaves, dryness of external peel associated with softening of bulb tissues. Harvest should be made when 1/3 of plants exhibit such signs. Harvest time is influenced by climatic conditions, purpose of marketing where early harvest leads to delay in dryness of bulbs, reduce quality and production whereas delaying harvest leads to increasing sunburn disorder, decreasing in storage ability and promoting fungal disease infestation. After curing treatment, crop is dry-cleaned (no washing is allowed to avoid diseases spread), then vegetative growth is eliminated, bulbs are sorted to exclude damaged, double and naked (with no external peal). Packing is made using suitable packs, and then the product is transferred to storage, either ventilated or refrigerated. Garlic can also be prepared as patches (green garlic patches) and left for dryness at good aerated places then transferred to storage, placed horizontally in layers.

**Thermal curing**

A critical and necessary process particularly for crop intended to be stored for long periods. This process can be applied in the field after harvest when humidity is low and can last for 3-7 days. Bulbs should be gathered after harvest and tied in patches where leaves of a patch cover the other patch to avoid sunburn. It can also be processed under shelters where patches are arranged in such a way to allow air ventilation or it can also be made using a thermal source in special rooms having heat source in one side and vacuum fans at the opposite side to enforce hot air to penetrate the packs. This method is fast but costly compared to doing it in the field. The best conditions for thermal curing treatment are 38$^{o}$C and 80% relative humidity not exceeding for one week.

**Suitable storage and transport conditions**

Temperature: 0$^{o}$C.
Relative humidity: 65-70%.
Pre-cooling: garlic is room-cooled.
Storage duration: garlic can be stored at ideal storage condition for 6-8 months. Storage ability is influenced by several factors such as:

1. Type of cultivar.
2. Thermal curing treatment: this treatment leads to closed neck region and external peel dryness which reduces weight loss and disease infestation.
3. Temperature and relative humidity: at ideal conditions, garlic can be stored for 6-8 months with no sprouting or large weight loss using sprouting inhibitors (before or after harvest).

Garlic is stored usually alone or with onion, because almost no other horticultural crop is stored at such low relative humidity, in addition to production of strong odor which can be absorbed by other crops. For short storage periods garlic can be stored at room temperature, hence can be stored with onion and potatoes. Garlic can be stored with onion at 0$^{o}$C and 65-70% relative humidity for more than 3 months.

**Physiological disorders**

- Sprouting: an important disorder, but using adequate holding conditions can limit or prevent this disorder, particularly when germination inhibitors are used before or after harvest. Irradiation at 8-10 krads can prevent sprouting and bulbs evacuation (breakdown).
- Rooting: occurs at high relative humidity in particular when storage period is prolonged.
- Sunburn.

- **Important diseases**
- Neck rot caused by *Botrytis* fungus.
- Bulbs breakdown caused by *Rhizobus* fungus.
- *Asparagellus* rot.
- *Penecillium* rot.
- Control include
  - Storage of full mature bulbs at high quality.
  - Thermal curing treatment.
  - Sorting of infected bulbs.
  - Fungicidal treatment.
  - Avoiding mechanical damages.
  - Storage at ideal conditions.

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# Lettuce ((*Lactuca sativa* L.)

Figure 1. Lettuce

Lettuce is fragile and must be handled with care to avoid mechanical damage and to minimize discoloration and pathological problems. Temperatures must be kept low and relative humidity high to prevent loss of turgor and wilting, and ethylene must be avoided.

**Quality characteristics and criteria**

In general, high quality lettuce should be clean, free of browning, crisp and turgid, and bright light green. Head lettuce should be solid, with no seed-stem, defects or decay.

**Horticultural maturity indices**

Head lettuce is harvested when the heads are well formed and solid. Maturity is based on head compactness, and the firmness of the head is related to its susceptibility to certain postharvest disorders. Soft heads are easily damaged while fairly firm heads have a higher respiration rates. Firm heads have maximal storage-life, while hard and extra-hard heads are more prone to develop russet spotting, pink rib and other physiological disorders.

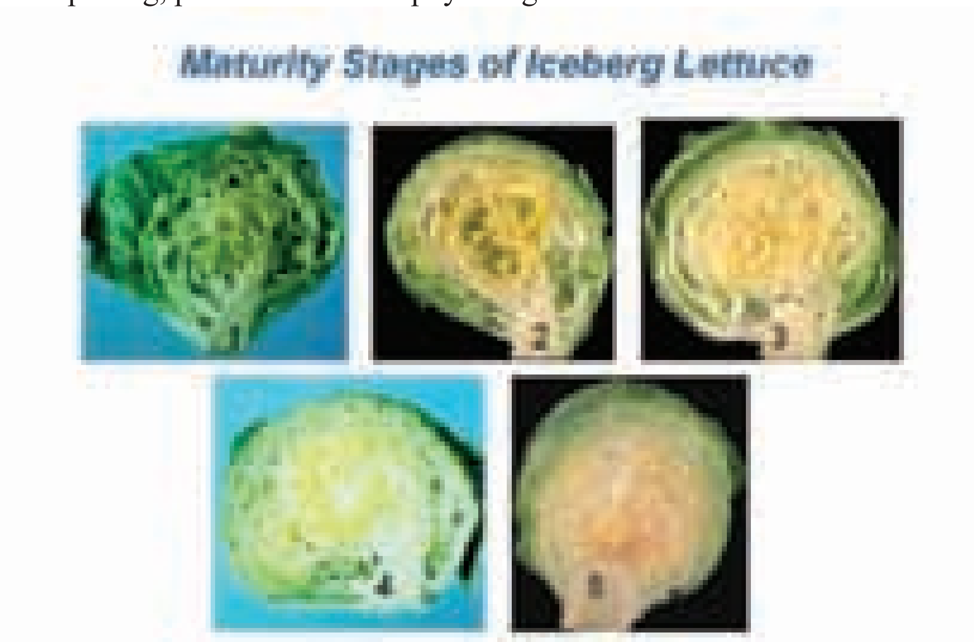


Figure 2. Maturity stages of iceberg Lettuce (Source: Dr. A.A. Kader).

**Grades and sizes**

Head lettuce is graded by size and firmness, while leafy types are graded by size. Lettuce, as with other leafy vegetables, must be kept clean and free of soil and mud. This is easier when grown on mineral than on muck (organic) soils. A strong bitter taste and toughness develops if harvest is delayed or if over-mature, and then the product becomes unmarketable.

**Harvesting and packing**

Lettuce is very fragile and therefore it should be handled carefully. Field packing and palletizing eliminate a major source of mechanical damage, but they require specialized handling equipment and vacuum cooling facilities to be practical. The stem is cut at ground level and the head trimmed of unusable leaves. Harvesting and field packing by hand is assisted by a variety of equipment that includes conveyors and mobile packing stations. Heads can be wrapped or bagged in plastic film by the cutter or packer. Wrapped or loose heads are then placed in cardboard containers that are closed, stapled and palletized. Leaf, butterhead and cos types are cut, trimmed and tied into compact bundles before placing in cartons. Crisphead or iceberg lettuce is usually packaged in 20 to 22 kg, 24-count cartons. Cos or Romaine lettuce is commonly packaged in 24-count cartons. Leaf lettuce is usually packaged in 9 to 11 kg or 24-count cartons. Butterhead and Boston lettuce are usually packaged in 9 kg cartons. Bibb and greenhouse grown lettuce are commonly packaged in 4.5 kg cartons. Lettuce harvested for processing is placed in large bulk bins for transportation to the pre-cooling or processing facility. Lettuce may be cored in the field or at local or regional processing facility. At the processing facility, heads are cut, washed in cold water, and centrifuged to remove excess water. Although most lettuce is hand harvested, some mechanical harvesters are available for product destined for processing into bag mixes.

Cut lettuce is often mixed with other types of lettuce or greens, shredded carrot and/or red cabbage to produce a bag of salad mix. The mix may be treated with a processing aid composed of a chlorine-containing compound and/or an antioxidant or preservative during washing or before packaging.

The package is usually made from special films that are selected to maintain a desired lower $O_2$ and higher $CO_2$ concentration than in air. The bags are then placed in cartons for temporary cold storage or for immediate shipment to market. Since gas composition in bags results from a dynamic interplay between tissue respiration and film permeability, it is important to maintain proper temperature and to know the respiratory characteristics of the enclosed tissue.

Potential for damage to the tissue and the induced higher rates of respiration and water loss require greater attention to maintaining the optimal storage conditions of temperature and relative humidity.

**Pre-cooling conditions**

Vacuum-cooling is the preferred method for pre-cooling all lettuces. For effective vacuum-cooling, containers and film wraps are perforated or readily permeable to water vapor. To facilitate cooling, clean water is sprinkled on the heads of lettuce prior to carton closure if they are dry and warmer than 25 °C. A modification called hydro-vacuum reduces water loss during cooling. Thorough pre-cooling is essential because mechanically refrigerated trucks do not have enough cooling capacity to cool warm lettuce during transit. Field heat retained in the densely packed cartons can be removed by forced-air where vacuum-cooling facilities are not available, but it is much less effective. Hydro-cooling is effective for non-heading lettuce types, but should not be used with head lettuce since the water retained in the head fosters decay.

**Optimum storage and shipping conditions**

- Lettuce should be quickly cooled and maintained as close to 0 °C as possible with 98 to 100% RH.
- Head types are better adapted to prolong storage than are the other types, but none keep longer than 4 weeks at 0-2°C, and about half that time at 5 °C.

- Film liners or individual polyethylene head wraps are desirable for attaining high RH; however they should be perforated or be permeable to maintain a non-injurious atmosphere and to avoid 100% RH on removal from storage.
- Lettuce is easily damaged by freezing, so all parts of the storage room must be kept above the highest freezing point of lettuce of -0.2 °C.

**Modified (MA) and controlled atmospheres (CA)**

- Lettuce, especially crisphead and fresh-cut respond favorably to MA/CA.
- Levels of 1 to 3% $O_2$ at 0 to 5 °C reduce russet spotting in susceptible lots.
- Intact heads do not benefit from elevated $CO_2$, and injury (brown stain) may develop when lettuce is transferred from storage in > 2% $CO_2$ to air at 10 °C.
- A 2 to 5% $O_2$ atmosphere maintains appearance of lettuce and inhibits pink rib and butt discoloration compared to air.
- Brown stain is intensified when $O_2$ is reduced to 2 to 3%, but the effect differs with cultivar.
- If lettuce needs to be shipped overseas for a month, an atmosphere of 2% $CO_2$ + 3% $O_2$ is recommended, because the reduction in decay achieved by 2% $CO_2$ outweighs the danger of injury.
- Romaine and leaf lettuce appear to tolerate a slightly higher $CO_2$ level when packaged than head lettuce.
- Browning is a major problem with fresh-cut lettuce, and is controlled by packaging in < 1% $O_2$ and 10% $CO_2$ atmospheres.
- The elevated level of $CO_2$ is more effective at reducing browning of the cut surfaces than it is at inducing brown stain.

**Retail outlet display considerations**

- Maintain cold conditions to maximize storage and shelf-life, minimize dehydration with periodic sprays of cold water.
- Avoid storage with commodities that produce ethylene; eg., apples, tomatoes. All types of lettuce are very susceptible to water loss, ethylene-induced disorders, and rapidly deteriorate at elevated temperatures.

**Ethylene sensitivity**

Ethylene production is very low, but exposure to ethylene can cause damage, such as russet spotting and leaf yellowing.

**Physiological disorders**

- Some of the more common disorders of head lettuce include tipburn, russet spotting, brown stain, and pink rib. Hard heads are more susceptible to these disorders than firm lettuce.
- Tipburn is of field origin, but occasionally increases in severity after harvest. Leaves with tipburn have brown, often necrotic leaf margins.
- Russet spotting, which is caused by exposure to ethylene and its induction of the synthesis, accumulation and oxidation of phenolic compounds at temperatures around 5°C, occasionally causes serious losses. Russet spots appear as dark brown, oval lesions on the midribs and on the green leaf tissue in severe cases. It is easily controlled by making sure the storage atmosphere is free of ethylene and that the temperature is at or slightly below 2°C.
- Lettuce should not be stored with ethylene producing commodities like apples, cantaloupes, pears, and peaches. Storage in a low $O_2$ atmosphere (1 to 4%) is very effective in controlling russet spotting.

- Brown stain is caused by exposure to higher than 2.5% $CO_2$ and appears as large, irregular shaped brown spots or streaks mostly on the midrib.
- Pink rib occurs in over-mature heads stored at elevated temperatures and appears as a diffuse pink discoloration of the midrib. The cause of this disorder is unknown.

**Postharvest pathology**

Bacterial soft-rot is the most serious disease of lettuce, often starts on bruised leaves, and result in a slimy breakdown of the tissue. A similar breakdown of tissue follows fungal infection by *Sclerotinia* and gray mold rot caused by *Botrytis cinerea*. Fast cooling, trimming and storage or shipping at 0-2°C greatly reduces the severity of these disorders.

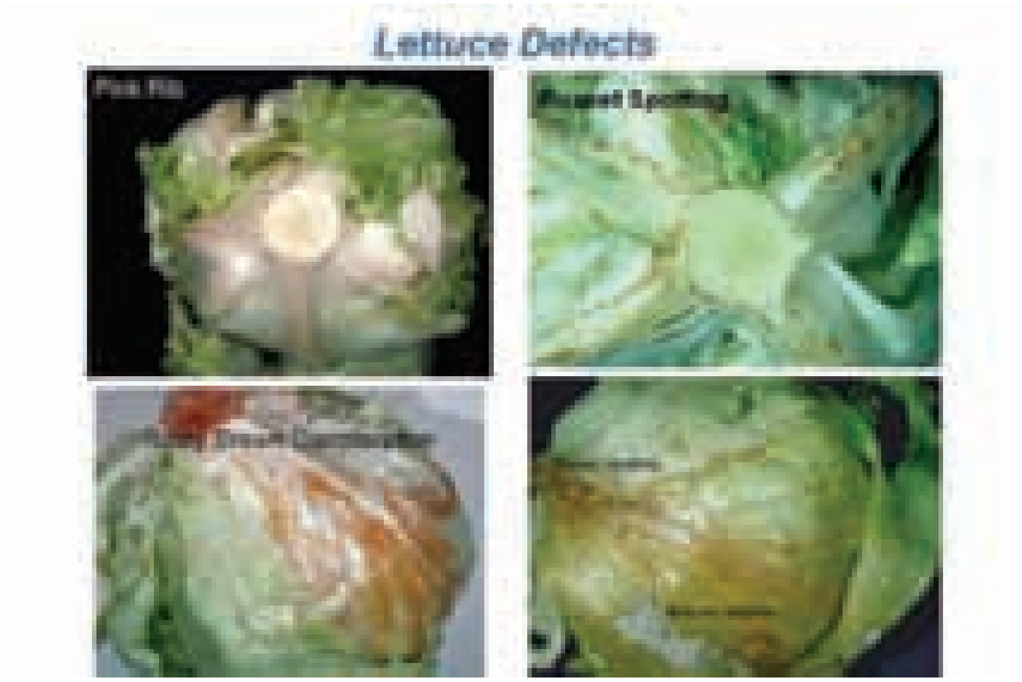


Figure 3. Some lettuce defects (Source: Dr. A.A. Kader).

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# Okra (*Abelmoschus esculentus* (L.) Moench)

Figure 1. Okra

Okra is a non-climacteric commodity, produces small amounts of ethylene (about 0.5 µL/kg/h) but it is characterized by high respiration rate (86 to 95 mg $CO_2$/kg/hr at 10°C).

**Quality characteristics**
High quality okra pods are 5 to 15 cm, flexible, bright-green and turgid, and seeds should not be protruding through the epidermis, and ridges should be free of blackening and bruising. Okra is graded by size and absence of defects, decay, insects and dirt, shape, and tenderness. Fancy pods are less than 9 cm; Choice from 9 to 11 cm; and Jumbo more than 11 cm.

**Maturity indices**
Okra pods are harvested when immature and high in mucilage, but before becoming highly fibrous; generally within 2 to 6 weeks after flowering.

**Packaging**
Fresh okra is most commonly presented in 0. 5 kg clamshell boxes or as bulk weight or volume-filled of about 11 kg bins.

Figure 2. Mature okra

**Cooling, storage and transport conditions**

Okra should be pre-cooled using hydro-cooling or forced-air cooling and should be marketed within 36 hour of harvest and shipped under refrigeration. Pods can be maintained for 7 to 14 days at 7 to 10°C and 90% or more RH. Storage in unventilated containers without refrigeration can cause degradation of color. Okra pods lose weight readily and are chilling-sensitive. There is only a very slight benefit from storage at 7 to 12 °C in 4 to 10% $O_2$, 5 to 10% $CO_2$ at 5 to 8°C and 3 to 5% $O_2$ + 0% $CO_2$, and high levels of $CO_2$ (> 20%) can cause off-flavors.

**Physiological disorders**

Okra pods are highly sensitive to chilling, especially when very young with more mucilageinous. Chilling symptoms can appear after storage for 2 days at 2°C, followed by 24 h at 20°C. They can be expressed as water-soaked or exuding lesions, with appearance of mold or mildew, especially if held at 5°C. Chilled green pods usually turn to brown-olive green color, yellow varieties turn brown, and burgundy varieties become a dull brown-red. Okra pods exposed to more than 1 ppm ethylene for 3 or more days show yellowing.

**Postharvest diseases**

Some of the important postharvest diseases of okra include *chladosporium*, gray mold (*Botrytis cinerea*), mildew, yeasts, *Rhizopus stolonifer*, *Rhizoctonia solani*, and *Psuedomonas* pv *syringae*.

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# Onions (*Allium cepa* L.)

Figure 1. Onions

Onion is a biennial of the *Alliaceae* family. The edible portions of the bulb are the enlarged leaf bases and compact stem. Green onions, also called scallions, are eaten for their immature bulb and green foliage.

**Quality characteristics and criteria**
High quality onions should have mature bulbs with compact fleshy scales, with adequate size, shape and color depending on the variety. They should be free of mechanical or insect damage, decay, sunscald injury, greening of fleshy scales, sprouting, bruising, doubles, bottlenecks, and any other defects.

Grades for green onions in the US include U.S. No. 1 and U.S. No. 2 based on external appearance and size. For U.S. No. 1, the overall length (excluding roots) must be 20 to 61 cm, and the diameter of the bulb 6.4 to 25.4 mm. Sizes are based on bulb diameter: Small: < 12.7 mm; Medium: 12.7 to 25.4 mm; and Large: > 25.4 mm.

**Horticultural maturity indices**
Dry onions, especially those intended for storage, should be harvested when 50 to 80% of the tops have fallen over and bulbs with a thin neck. Yield is higher when harvested after the tops are completely dry, but bulbs tend to have a shorter postharvest life. Bulbs can be undercut by a blade about 7 days prior to lifting, although these onions will not withstand long-term storage. Onions for bunching can be harvested from pencil size until they have proper bulb size.

**Curing**
Onions intended for storage should be dried and cured in the field (under shed) or in storage. After 2 weeks of field drying, onions can be transferred to storage rooms for final drying and curing. Forced-air ventilation at 25 to 27°C using outside or heated air is commonly used to dry onions. Onions can be stored and dried on the floor in bulk, 3 to 4 m deep, or in 500 to 1000 kg boxes. Drying is complete when the onion neck is tight, outer scales are dry and make a rustling noise when touched, and the skin color is uniform. Weight loss of 3-5% can occur during drying.

Losses from neck rot are reduced by rapid drying immediately after harvest. After drying and curing, the temperature should be lowered gradually to 0 °C. Water condensation should be avoided during storage as it encourages rot and changes the color of the dry skin.

**Packaging**
Trimmed green onions are bunched and marketed as bulb-type in 9 and 12 kg cartons, and as 24, 36 and 48 count, bunched in 9, 5.0 and 6 kg containers, respectively.

**Cooling, storage and shipping**
Bunched green onions should be pre-cooled to less than 4 °C within 4 to 6 hours of harvest, using hydro-cooling, forced-air cooling or vacuum-cooling. Crushed ice can also be used over the product to maintain low temperature and high moisture. They can be stored 3 to 4 weeks at 0 °C and 95-98% RH. Bunched onions stored in polyethylene-lined containers and top-iced maintain good quality for 1 month. Storage-life decreases to 1 week if the temperature is 5°C, and higher temperatures can cause rapid yellowing and decay of leaves.

Dry onion bulbs for long-term storage should be cooled to 0 °C immediately after drying. Cooling can inhibit rooting and sprouting during storage. Natural cooling, used in some countries (slow cooling) has a positive effect on storability when onions have a long rest period and when weather conditions are good for curing. Pungent, dry onions can be stored for 6 to 9 months at 0 °C and 65-75% RH. High RH induces root growth, while high temperature induces sprouting, and a combination of both increases rotting and decreases quality. Mild type or sweet onions can be kept for 1-3 months in common storage with cool, circulating ambient air (where temperature is not high) or in refrigerated cold rooms. Onions grown from seed commonly store better than those grown from sets or transplants.

After harvest, onion bulbs enter a state of rest for a period of 4 to 6 weeks, depending on cultivar and weather conditions. Maleic hydrazide, a sprouting inhibitor, can be used to prevent root growth and sprouting during long-term storage. It is applied 2 weeks before harvest, when bulbs are mature and 50% of tops are down, but plants must still have five to eight green leaves in order to absorb and translocate the sprout inhibitor to bulbs.

For cold storage, onions are usually packed in crates or containers. Air circulation must be sufficient to maintain a constant temperature and to remove moisture from inside storage containers. Onions packed in sacks can only be stored for a limited period of time, about 1 month, since air movement through sacks is insufficient to maintain proper storage conditions. When stored below - 1 to -2 °C, onions should be thawed at 5 °C for 1-2 weeks before they are removed from storage. Rapid thawing damages onion bulbs. Mild and sweet onions can be stored for only 1-4 months at optimum storage conditions, but controlled atmospheres can extend storage life. Onions can tolerate storage at 30-35°C for short periods before marketing or processing, but their quality and external color is less attractive than cold-stored onions.

Bunched green onions can be stored for 6-8 weeks in 2% $O_2$ + 5% $CO_2$ at 0 °C. They can tolerate 1% $O_2$ and up to 5% $CO_2$, but off- flavor may develop if stored at > 5 °C. Controlled atmospheres have been used for storage of pungent onions in some European countries, where 3% $O_2$ + 5% $CO_2$ atmosphere inhibits rooting, sprouting and disease development.

Figure 2. Mature onion

**Physiological disorders**
Greening is caused by exposure to light and can be prevented by storing in the dark.
Freezing injuryresults in soft, water-soaked fleshy scales and rapid decay after transfer from cold storage to higher temperature. Watery scales include thick leathery skin, which when peeled away, reveals watery, glassy, fleshy scales below, resulting from late harvesting and prolonged drying.

**Postharvest diseases**
Blue mold rot is commonly expressed as watery soft rot of neck and outer scales, followed by formation of blue to blue-green mold of the fungus *Penicillium* spp. Harvest of mature bulbs, proper curing, and storage at 0 °C at 60-70% RH reduces the problem of this decay. Bacterial soft rot can appear as water soaked individual scales or the entire onion, with off/flavors, rotted areas caused by *Erwinia carotovora*, and the infection progresses rapidly under warm, humid conditions. Harvesting at full maturity, proper drying, minimizing bruising and maintaining the bulbs at 0ºC and 65-70% RH prevents this problem. Botrytis neck rot is a watery decay that begins at the neck and then attacks the entire bulb, followed by a gray fungal mold that covers the neck of the bulb and later the whole bulb surface. It can be reduced after harvest especially by proper drying, but not stopped, even under optimum storage conditions. Black mold rot is caused by caused by *Aspergillus niger* and appears as a black discoloration and shriveling at the neck and on outer scales. Infection usually occurs in the field but spreads after harvest. Dried bulbs and storage at 0°C and low RH prevents the spread of this disease.

Figure 4. Reddish-brown discoloration of onion scales caused by *Botrytis* neck rot

Figure 3. Gray sporulation of *Botrytis* neck rot.

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# Parsley (*Petroselinum crispum* (Mill.)

Parsley has very high vitamin and nutrient content. It is highest in calcium, iron and folate of most vegetables, and among the highest contents of β-carotene, thiamin, riboflavin and vitamins C and E. It has an important content of the carotene 9-cis β-carotene, which has been associated as active against cancer and cardiovascular disease. Parsley contains furocoumarins, including psoralen, which are effective antimicrobial agents, but can act as phototoxins inducing dermatitis. Parsley is used as a medicinal plant to treat hypertension in Morocco and diabetes in Turkey.

**Quality characteristics**
High quality parsley should be fresh, with green color, free from defects or seed stems and free from decay. Long petioles are desirable for bunching.


Parsley color rating scale (Source: Dr. Adel Kader).

**Harvesting and packaging**
Parsley is hand harvested, either progressively or cut all at one time. It is commonly packaged in cartons or jumbo crates of 60 bunches, with a capacity 9 to 11 kg.

**Cooling, storage and shipment**
Parsley is very perishable, with extremely high respiration rate, and it is very susceptible to wilting and yellowing especially due to ethylene exposure. Therefore, rapid cooling (rapid removal of field heat) without excessive drying is very important to maintain green color and freshness. Parsley can be pre-cooled with ice (package icing) or liquid-icing or by vacuum-cooling, but forced-air or hydro-cooling can also be used. Optimum storage and transport conditions are 0°C and 95 to 100% RH, where parsley can be maintained for 1 to 2 months, compared to only 3 days at 18-20°C and 85-90% RH. Modified atmosphere packaging (MAP) is effective in extending storage-life, but temperature changes and condensation inside the package must be avoided. Over 2 months storage can be achieved in MAP (using a 40 µm-thick ceramic film) at 0°C or 35 days at 5°C, with good retention of firmness and vitamin C content,. Pre-harvest spray with gibberellic acid can also extend storage-life. Parsley can tolerate 8-10% $O_2$ + 8-10% $CO_2$, but this may be of little benefit at 0°C, but 10% $O_2$ + 11% $CO_2$ can be beneficial for delaying yellowing in parsley stored at 5°C, and storage in 10% $O_2$ + 10% $CO_2$ can delay yellowing at room temperature. Using of ice or water sprays during retail display is recommended.

**Physiological disorders**
Wilting (loss of water) and yellowing are the most important physiological disorders of parsley signal the end of shelf-life. Parsley leaves produce very little ethylene (about 0.08, 0.44 and 0.80 µL/kg/hr at 0, 10 and 20°C) but are very sensitive to ethylene, where as little as 0.4 ppm is enough to accelerate yellowing if parsley is stored above 0°C.

**Postharvest pathology**

The most important decay pathogens that affect parsley are *Erwinia* and *Botrytis*. Microbial safety is an important handling factor for parsley, because of some potential infectious agents such as *Shigella*, *Citrobacter freundii* (causing gastroenteritis and hemolytic uraemic syndrome) and thermotolerant campylobacters. The use of chlorinated water is somewhat beneficial in reducing this risk, but personal hygiene of staff is much more important.

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# Peppers

**Figure 1. Peppers**

Being non-climacteric, peppers need to be harvested at full maturity. They are very sensitive to water loss where most loss occurs at fruit-plant junction. They are also sensitive to cold injury. Mechanical injuries increase water loss and disease infestation. Therefore, it is important to handle peppers very carefully.

**Quality characteristics and ripening indices**

- Bright green color and waxy appearance.
- Uniform shape and size.
- Free of sunburn, wounds and scratches.

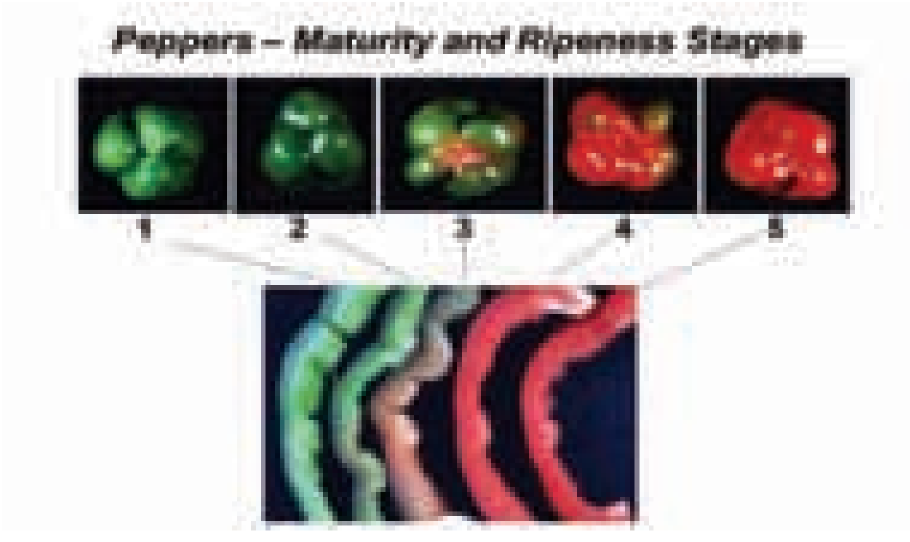


Figure 2. Peppers maturity and ripeness stages in bell peppers (Source: Dr. A.A. Kader).

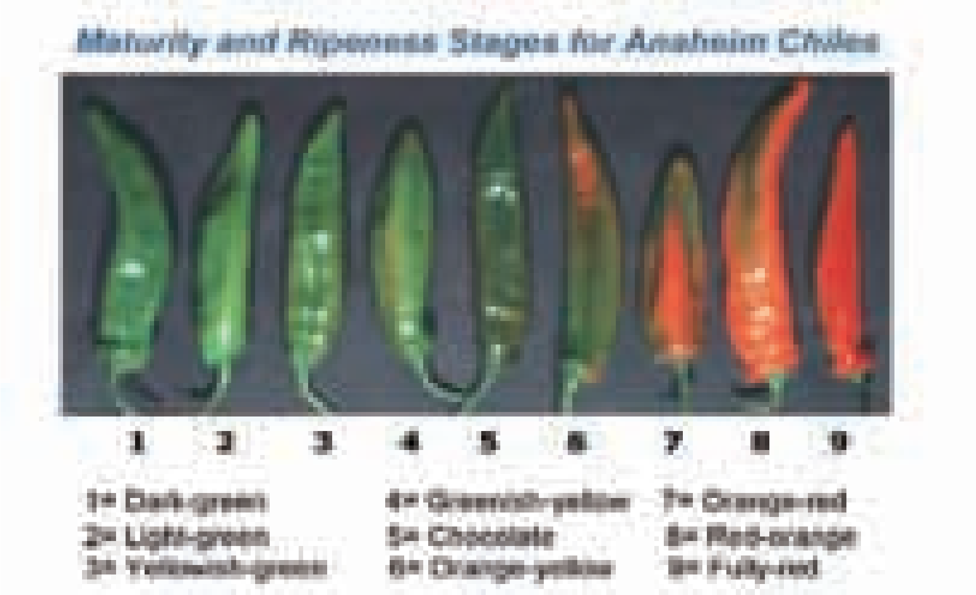

Figure 3. Maturity and ripeness stages for Anaheim Chiles (Source: Dr. A.A. Kader).

**Suitable storage and shipping conditions**

- Temperature: 7 – 10$^{o}$C.
- Relative humidity: 95%
- Storage duration: At optimal condition fruits can be stored for 2-3 weeks.
- Fruits are injured by cold storage at lower than 7$^{o}$C, reducing fruits storage ability and marketing.
- For short periods (one week or less), pepper fruits can be stored with cucumber, eggplant, okra, orange, ripe tomato and summer cucurbits at 7-10$^{o}$C and 90-95% relative humidity.
- For long periods (more than a week), pepper fruits can be stored at 7-10$^{o}$C and 95% relative humidity with eggplant, olives, ripe tomato, summer cucurbits.

**Harvesting and fruits preparation**

- Fruits are harvested at full mature stage.
- Fruits are picked manually.
- Packing can be done in the field (for local markets), or in a packinghouse where the following processes are applied to insure good quality fruits during shipping, storage and marketing:
    - Cleaning and washing.
    - Sorting to exclude poor and undesired quality.
    - Grading according to size and color.
    - Manual packing.
    - Pre-cooling.
    - Marketing or storage.

**Physiological disorders**

Chilling injury occurs at temperatures lower than 7$^{o}$C and appears as surface pitting, and fruit becomes very susceptible to diseases.

Water loss leads to wilting and reduces marketability. Proper handling conditions including proper temperatures, high relative humidity and waxing can help reduce this problem.


Figure 4. Chilling symptoms on peppers (Source: U.C. Davis).

**Important diseases**

Soft bacterial rot appears as watery stains with unpleasant smell. Soft rot appears as watery stains and fungal black spores, which can be reduced by avoiding mechanical damage and cold injury. Alternaria rot occurs in particular in chilling injured fruits. Gray mold can be avoided by reducing mechanical injury.


Figure 5. Decay caused by *Erwinia* (Source: Dr. A.A. Kader).

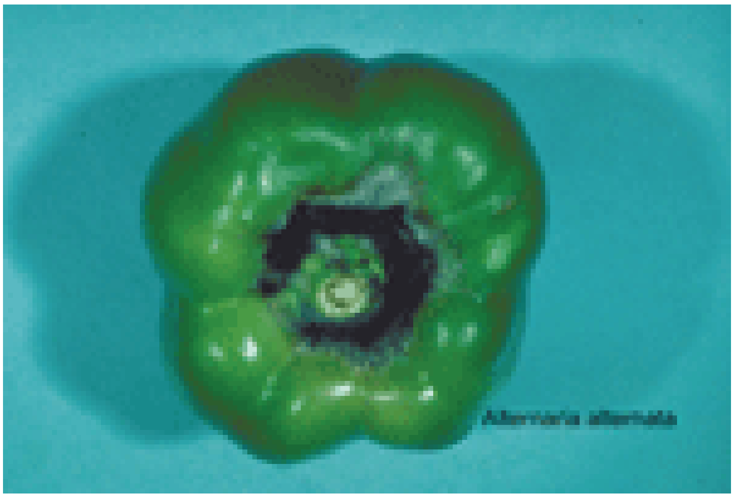


Figure 6. Decay caused by *Alternaria* (Source: Dr. A.A. Kader)

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# **Potato** (*Solanum tuberosum* L.)

Figure 1. Potato

Potato is a cool season plant, grown throughout the temperate zones. There are several skin (brown russet, white, red, pink, yellow) and flesh (white, cream, yellow, blue/purple/red, and striated) colors, and tuber shapes (round, oblate, oblong to long). It is non-climacteric with very low levels of ethylene (< 0.1 µL $kg^{-1}$ $h^{-1}$ at 20°C), and very low respiration rate (6 to 18 mg $CO_2$ $kg^{-1}$ $h^{-1}$ at 5°C).

A high quality fresh-market potato tuber should be turgid, well shaped, uniform, brightly colored (especially reds, whites and yellows), free from adhering soil, mechanical damage, greening, sprouts, diseases, and physiological defects.

Figure 2. Different types of potatoes in Peru
(Dr. Elhadi Yahia).

**Harvesting indices and harvesting**

Harvesting indices in potato include the ability of potato tuber skin to resist abrasion (skinning) during harvest and vine senescence. It is important to avoid harvesting immature tubers, to avoid skinning, which would increase water loss, and cause tuber browning.

Potatoes are harvested manually, semi-mechanical or mechanical. Some new harvesting machines are equipped with means to separate, grade and pack. It is recommended to stop irrigation 2-3 weeks before harvest to promote the wilting of the vegetative part and the formation of the skin of the tuber. It is also important to avoid the exposure of tubers to direct sun light and thus to avoid greening.

**Sprout inhibitors**

Sprout inhibitors may be applied in the field before senescence begins, after harvest when tubers are graded and packaged, or in storage after curing is completed. These are used to prolong the rest period of the tubers, inhibit sprouting, and thus prolong storage life. Maleic hydrazide at 2000 to 2500 ppm is commonly used about 4 weeks before harvest. Some of the sprout inhibitors used after harvest include CIPIC (at 1 gm for each 80 Kg of potatoes), Luxan (at 20 mL for each 1000 Kg of potatoes) and MENA (at 1 gm for each 20 Kg of potatoes).

Irradiation at very low doses (0.05-0.15 KGy) is very effective and commonly used in several countries for many years to inhibit sprouting and to prolong storage life of potatoes.

Figure 3. Potato packing house

**Packing and packaging**

Potatoes are commonly packed in packinghouses, where they are washed, sized, graded and packaged. Several types of packages are used for potatoes. Bins with a capacity of 250 Kg or more are sometime used for storage. In some countries potato is also stored in sacs of a capacity of 50-80 kg. The crop is marketed in a diverse types of packages including sacs and wooden or carton boxes of diverse capacities.

Figure 4. Potato package
(Dr. Elhadi Yahia)

Figure 5. Potato carton packages

**Optimum storage and shipping conditions**

Potato can be stored for a long period of time (up to 12 months), if handled adequately, and especially if cured. Curing stimulates suberization and wound healing, reduces respiration rate, water loss and disease infection. Optimal curing conditions are about 20 °C and 80-100% relative humidity (RH) for 3-12 days depending on temperature and RH, and it is slow at temperatures less than 10-12°C and more than 25-30°C, and also at less than 80% RH. Curing at 15°C is recommended to minimize decay. Once cured, the tuber temperature is lowered by 1 to 2°C per day until the desired holding temperature and RH are reached.

Optimum holding temperature depends on the desired end use of potatoes. Respiration rate of potato tubers is lowest at 2 to 3°C. Storage at 0 to 2°C increases the risk of freezing or chilling injury. Sprouting accelerates at temperatures higher than 4 to 5°C. Tubers for fresh consumption are stored at 7-10°C, to minimize conversion of non-reducing sugars such as starch to reducing sugars such as glucose, which darken during cooking. Accumulation of reducing sugars increases at low temperature and it is maximum at 4°C. During processing, reducing sugars are reacted with amino acids (Mailard reaction) producing a dark color. Therefore, tubers for frying are commonly stored at 10-15°C to promote the conversion of reducing sugars to starch. Potato cultivars differ in their susceptibility to accumulate reducing sugars at low temperatures. For example, it is faster in Norship than in Kennebec (a variety commonly used for processing) potatoes. The accumulation of reducing sugars is also influenced by several other factors such as harvesting time, soil temperature and humidity. Some new cultivars are being developed that will not accumulate sugars at temperatures as low as 5-10°C.

Air circulation in storage is very important to promote a uniform temperature and gas concentration in the store, and to avoid formation of hot spots, and increase in decay. Adequate cold air circulation can only be insured by using adequate packages and by stacking them adequately.

Potatoes may impart an "earthy" odor to apples and pears and may acquire off-odors from other products, especially if held in storage with low air exchange.

**Physiological disorders**
Sensitivity to temperature: potatoes freeze at approximately -1°C, internal mahogany browning can occur at 1-2°C, and starch can be converted to reducing sugars at 3-4°C.

Black spot: blackening of the tissue resulting from a physical impact to the tuber and the stem end of the tuber is the most sensitive.

Blackheart: a storage induced disorder caused by low $O_2$, and increased at higher than 30°C.

Greening: a common problem resulting from exposure of the tubers to light in the field, during storage, during displays in market or at home. Darkness (including holding potatoes in dark packages such as black sacs) can avoid greening and may even eliminate the developed green color. Green color may contain chlorophyll and bitter, toxic glycoalkaloids, such as solanine, which are heat stable and minimally degraded by cooking.

Hollow heart: sugar accumulation and internal necrosis resulted during production, and may be caused by irregular growth, inadequate water availability and fluctuating temperatures.

**Diseases**
Diseases in potato can be initiated in the field or after harvest, and can cause significant losses. These are caused by several bacteria and fungi such as bacterial soft rot *(Erwinia carotovora subsp. carotovora and subsp. atroseptica), Ralstonia* (ex *Pseudomonas,* ex *Burkholderi) solanacearum,* late blight (*Phytophthora infestans)*, Fusarium dry rot (*Fusarium* spp.), pink rot (*Phytophthora* spp.), water rot (*Pythium* spp.) and silver scurf (*Helminthosporium solani*), pink eye (*Pseudomonas fluorescens*) and grey mold (*Botrytis cinerea*). Some diseases and nematodes are quarantined in some countries, such as cyst nematode (*Globodera spp.*), viruses and viroids, brown rot (*Pseudomonas solanacearum*), ring rot *(Corynebacterium sepedonicum)* and powdery scab (*Spongospora subterranean*).

Several factors promote disease infection and spreading, such as cuts and other mechanical damage and rough handling, holding at high temperatures, very high RH which may cause water condensation, lack of adequate cold air circulation in the store which can lead to high temperatures and RH.

Adequate handling is important to reduce disease development. Harvesting should be done adequately to reduce cutting and mechanical injury. Curing should be done adequately using adequate temperature and RH. Tubers should be adequately sorted before storage to eliminate culls and tubers with any other problem. Store should be adequately managed with respect to staking packages adequately, using optimum temperature and RH, and insuring adequate air circulation.

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# Pumpkins and winter squash

Pumpkin (*Cucurbita pepo* L.)
Winter squash and giant pumpkin (*Cucurbita maxima* Duchesne ex Lam.)
Crookneck squash, tropical pumpkin (calabaza)
Butternut squash (*Cucurbita moschata* (Duchesne ex Lam.) Duchesne ex Poir.)

Pumpkins have coarser, stronger flavored flesh. Winter squash have finer textured and milder flavored flesh.

**Quality characteristics**
Pumpkins and winter squash are non-climacteric and they should be fully mature when picked, with hard rinds and, except for some striped varieties, solid external color. Flesh of good quality pumpkins and winter squash are bright yellow or orange with fine, moist texture and high solids, sugars, and starch, and over-mature flesh can become dry and stringy.

**Maturity indices**
Maturity can be recognized by corking of the stem or initiation of abscission, loss of rind surface sheen or gloss, ground spot yellowing, and die-back of the tendril nearest to the fruit. This is coincides with development of intense yellow or orange flesh color due to formation of carotenoids.

**Packaging**
Used packages are commonly mesh or burlap bags and one- or two-piece fiberboard cartons containing about 23 kg, although pumpkins and winter squash are also shipped in 20-kg crates and 360 to 400 kg bulk bin cartons.

**Cooling and storage and shipping conditions**
Pre-cooling is not needed and therefore not commonly used for these products. They can be cooled in a room, but many times are loaded directly into the refrigerated trucks and containers without pre-cooling and in other cases are transported in non-refrigerated containers.

All pumpkins and winter squashes should be well matured, carefully handled, and free from injury or decay when stored. They are commonly placed on racks, in bulk bins, or in baskets and are often held in ventilated or common storage, sometimes in production areas. These products are chilling sensitive and recommended storage and shipping conditions are 10-13°C and 50 to 70% RH for a maximum of 2-3 months for most cultivars of winter squash, pumpkins and tropical pumpkins. Corn-type squashes can be kept for 5 to 8 weeks at 10°C, and butternut squash can be kept 2 to 3 months at 10°C. Green varieties will become undesirably yellow and acquire a stringiness of the flesh at 15-20°C. Fruit surface should be kept dry, and storage rooms should have good air circulation. All pumpkins and winter squash types can be displayed in ambient conditions.

Pumpkins and winter squashes develop chilling injury at less than 10°C, and symptoms develop after 1 month at 5°C or several months at 10°C. Storage at 0-4°C inhibits yellowing, causes sunken pits on the fruit surface and loss of flavor, and *Alternaria* rot develops on chilled squashes after removal from storage.

Yellowing can be a problem for green winter squash varieties and is exacerbated by over-maturity, high storage temperatures, and ethylene exposure.

Pumpkins and winter squash produce very low amounts of ethylene, however the exposure of hubbard squash and other dark-green-skinned squashes can cause the skin to turn orange-yellow, in addition that ethylene may also cause stem abscission; especially in less mature fruit.

**Postharvest diseases**
Diseases are the major cause of postharvest losses in pumpkins and winter squash. Some of the fungi-causing rots include *Aspergillus*, *Colletotrichum* (anthracnose), *Didymella*, *Fusarium*, *Mycosphaerella* (black rot), *Rhizopus*, *Sclerotinia*, and Alternaria. Careful handling to minimize mechanical damage is recommended to minimize decay. Hot water treatments at 60°C for 2 minutes can reduce storage rots.

**Curing**
Curing for 10 days to 3 weeks at 24 to 27 °C before storage can harden the rind of pumpkins and winter squashes and reduced losses.

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# Red pumpkins

Red pumpkin is a member of the *Cucurbitaceae* family.

**External characteristics**
Red pumpkin fruits are harvested at mature stage, and are sensitive to cold injury.

**Quality characteristics and maturity indices**

- Uniformity at ripening stage in shape, size and weight.
- Freedom from mechanical injuries.

**Proper storage conditions**

- Temperature: 12 – 14$^{o}$C
- Relative humidity: 60 – 70%.
- Storage duration: 4-6 months.

**Mixed storage with other crops**
Avoid storing red pumpkin fruits (sensitive to chilling) with other crops that can withstand low temperature (less than 12$^{o}$C). Red pumpkin can be stored with lemon, green tomato and other crops sensitive to cold for a short period, but for a long storage periods it is preferred to store red pumpkin in separate rooms due to unfit optimal relative humidity (60-70%) with RH of required by other crops despite of suitability of optimal storage temperature as in lemon and green tomato.

**Physiological disorders**
Chilling injury appears as colored notches at surface, usually becoming sites of disease infection, sometimes associated with brown internal stains on the peel leading to more susceptibility to diseases. Storage at optimal temperature, heat treatments and dipping in calcium can reduce cold injury. Flower end rot occurs as a result to irregular irrigation and calcium deficiency, and sunburn occurs where fruits are exposed to hot sun light particularly when harvest is delayed.

**Important diseases**

- Soft bacterial rot.
- *Rhizobus* rot.
- *Alternaria* rot.

# Radish (*Raphanus sativus*)

**Quality characteristics**
Good quality radishes should be well-colored, tender and firm, with no ridges, and free from dirt or other foreign materials, harvest cuts and abrasions.

**Maturity indices**
Size is commonly used as a harvest index depending on the type of consumers.

**Packing and packaging**
Radishes are washed and commonly graded according to diameter. Packages are very variable. They are commonly packed in plastic perforated bags, and may then be hand-packed into wax cartons and stored or shipped.

**Cooling, storage and shipping**
Pre-cooling, commonly done by hydro-cooling to 0- 5°C, is important for mainataining radish quality. Bunched radishes are commonly dipped in chlorinated water to remove field debris and for disinfection. After packing into the waxed cartons they can be hydro-cooled, and also the cartons can also be topped with ice slurry before shipping.

Topped radishes can be held 3-4 weeks at 0°C and 90 to 95% RH, and at least 7 days at 7.2°C. Bunch radishes are harder to keep fresh due to the perishability of the tops, but they can be held at 0°C and 90 to 95% RH for 1-2 weeks, although winter or black radishes can be stored under the same conditions for 2 to 4 months. Addition of top ice in the carton package can maintain the freshness of the radish tops. During display, packaged radishes should be placed in a refrigerated rack. Bunch radishes should be refrigerated, and can be iced or misted to help preserve quality.

Radishes produce small amounts of ethylene and are not sensitive to ethylene exposure.

**Physiological disorders**
Radish is not sensitive to chilling injury. Growth cracks or air cracks reduce quality when they are more 6 mm deep. Over-maturity or stress during growth can induce dry, cottony voids in the root called pithiness. Yellowing of tops can result from over-maturity or exposure to ethylene or elevated storage temperature.

**Postharvest diseases**
Important diseases include bacterial black spot (*Xanthomonas vesicatoria*), downy mildew (*Peronospora parasitica*), *Rhizoctonia* root rot (*Rhizoctonia solani*). Avoiding bruising, hydro-cooling to 4°C, washing in chlorinated water (100-200 ppm), and storage or shipping at 0-2°C can reduce these problems.

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# Summer squash (*Cucurbita pepo*)

**Quality characteristics**
Important quality characteristics of summer squash include tenderness and firmness, shiny surface, and freedom from physical injury. Yellowish signs are sign of senescence in dark green types. Water loss results in a dull surface and loss of firmness. Size is an important quality characteristics, but vary greatly from less than 50 g to more than 400 g), depending on the type of squash and market demand.

Fig. (1): Summer Squash

**Maturity indices**
Summer squash are harvested when they are still shiny in appearance , usually up to 1 week after anthesis, with small fruit more desirable than larger ones because their flesh and seeds are tender.

**Packing and packaging**
Squash may be field packed directly into shipping containers or transported to the packinghouse in field boxes or bulk bins for washing and sizing before packing. Packages used include baskets, wire-bound wooden crates and fiberboard boxes, and a plastic liner should commonly used in wooden containers to prevent abrasion and retard water loss.

Summer squashes are extremely tender and can be injured very easily by physical and mechanical problems, and therefore, they should be handled gently throughout the whole postharvest chain, including that pickers and packers should wear cotton gloves to prevent fingernail cuts.

**Cooling, storage and shipping**
Fast pre-cooling to remove field heat immediately after harvest, using room, forced-air or hydro-cooling, is important to reduce water loss and to extend postharvest life. Summer squash are highly perishable and not suited for storage longer than 2 weeks, and should be maintained at 5 to 10°C and 95% relative humidity. During display, they should not be stacked more than four layers deep and should be arranged carefully so they do not fall off the rack, which should be refrigerated, however, direct contact with ice should be avoided because it can cause chilling injury and physical damage.

**Physiological disorders**

Summer squash are chilling sensitive when exposed to temperatures below 5°C, however, there are great variation in chilling tolerance among the different types. Chilling symptoms include surface pitting, increased water loss, increased ethylene production, and decay that become obvious especially when fruit is transferred to non-chilling temperature. Summer squash are very susceptible to water loss, and shriveling may become evident with as little as 3% weight loss. Because fruit is very tender, skin breaks and bruises can be a serious source of water loss and microbial infection. It produces low to moderate amounts of ethylene (0.1 to 1.0 µL kg/h/ at 20°C), but exposure of ethylene increases fruit yellowing of green skinned summer squash. Pre-cooling and storage at low (optimum) temperature and high RH minimize weight loss. Waxing (with thin coatings) provides some surface lubrication that reduces chaffing in transit.

**Postharvest diseases**

Decay caused by fungi and bacteria is a major cause of postharvest losses in summer squash, and it increases due to physical and chilling injuries. Common postharvest diseases include *Alternaria* rot, bacterial soft rot, cottony leak, *Fusarium* rot, *Phythopthora* rot, and *Rhizopus* rot. *Alternaria* rot can occur following chilling injury.

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# Tomato (*Lycopersicum esculentum*)

Figure 1. Greenhouse tomato production (Source: Dr. Elhadi Yahia).

Tomato is the most consumed vegetable crop in the world. It is cultivated in fields in (temperate) mild environments or in greenhouses at cold regions or during winter in temperate zones.

**External characteristics:**

- Surface area of fruit to weight is low therefore tomato is moderate in water loss (wilting). Most water loss (60%) occurs through stem-fruit connection.
- Mechanical injuries lead to water loss and increase in diseases infection which in turn enhances ripening process.

**Physiological characteristics**

- A climacteric fruit.
- Sensitive to chilling injury.
- Can be harvested mature-green then ripened artificially.
- Green tomato fruits are more sensitive to chilling injury than fully matured fruits.

Figure 2. Different stages of fruit ripening (Source: Dr. Elhadi Yahia).

**Harvest and ripening indices**

Color is the most important maturity index used for tomato. Fruits are divided according to color to: full mature-green, breaker, turning, pink and red. Fruits are picked at any of the mentioned stages according to purpose. Harvest at mature green stage is adequate for long distance transport or for storage.

Figure 3. Tomato green-house operations (Source: Dr. Elhadi Yahia).

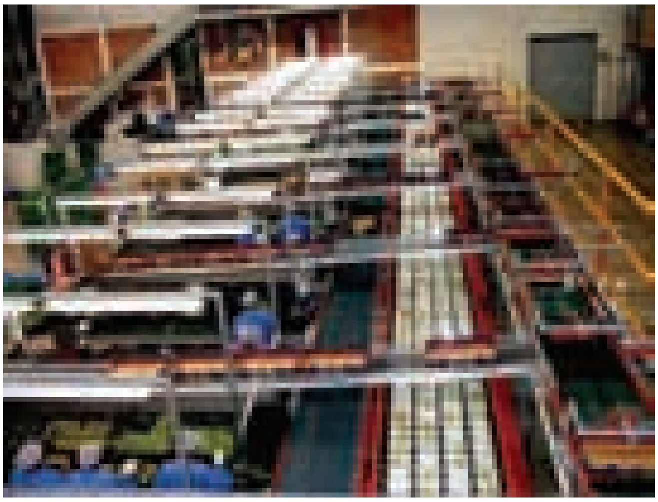

Figure 4. Tomato packing (Source: Dr. Elhadi Yahia)

Figure 5. Tomato wooden package (Source: Dr. Elhadi Yahia).

Figure 6. Tomato package (Source: Dr. Elhadi Yahia).

**Storage an shipping conditions**
Mature -green fruits should be maintained at 13°C and 90-95% relative humidity, and colored fruits at 5-7°C and similar relative humidity. Storage duration for green tomato is about 3-4 weeks while colored ones can be stored for 3-10 days.

**Mixed storage with other crops**
Green tomato can be stored with citrus fruits whereas red colored tomato can be stored with pepper, eggplant, olive, watermelon and summer cucurbits as they require similar to optimal temperature and relative humidity.

**Preparation of fruits**
Fruits are picked by shears or by hands and deposited in field or marketing packs or transferred in field boxes or trucks to packing houses. Fruits are washed by water (sometimes cold water to remove field heat), and chlorine gas and fungicides can be added to washing water. Fruits are dried to remove excessive water or humidity, and graded according to ripening stage and to size, packed in suitable carton packs, and then pre-cooled to 13°C and stored or shipped.

**Artificial ripening**
This process is done at 15-25°C (depending on required ripening speed), and 85-90% relative humidity with 100-200 ppm of ethylene.

**Physiological disorders**
Tomato is sensitive to chilling injury (CI) with mature-green fruit the most sensitive stage, when temperature decreases below 13°C, red fruits can be injured when temperature decreases to 4°C. CI induces irregular or failure in coloration of fruits with deep strains on fruit surface depending on the time of exposure to low temperature and severity of injury. Tomato fruit is also sensitive to high temperature injury, where temperatures higher than 30°C may lead to injury and low quality, in addition to irregularity in ripening. Both problems can occur in the field or after harvest.

**Postharvest diseases**
Important diseases affecting tomato fruit are soft bacterial rot, *Alternaria* rot, and *rhizobus* rot. Disease control is achieved through good handling of fruits to reduce mechanical damage and storage at safe temperature and optimal relative humidity.

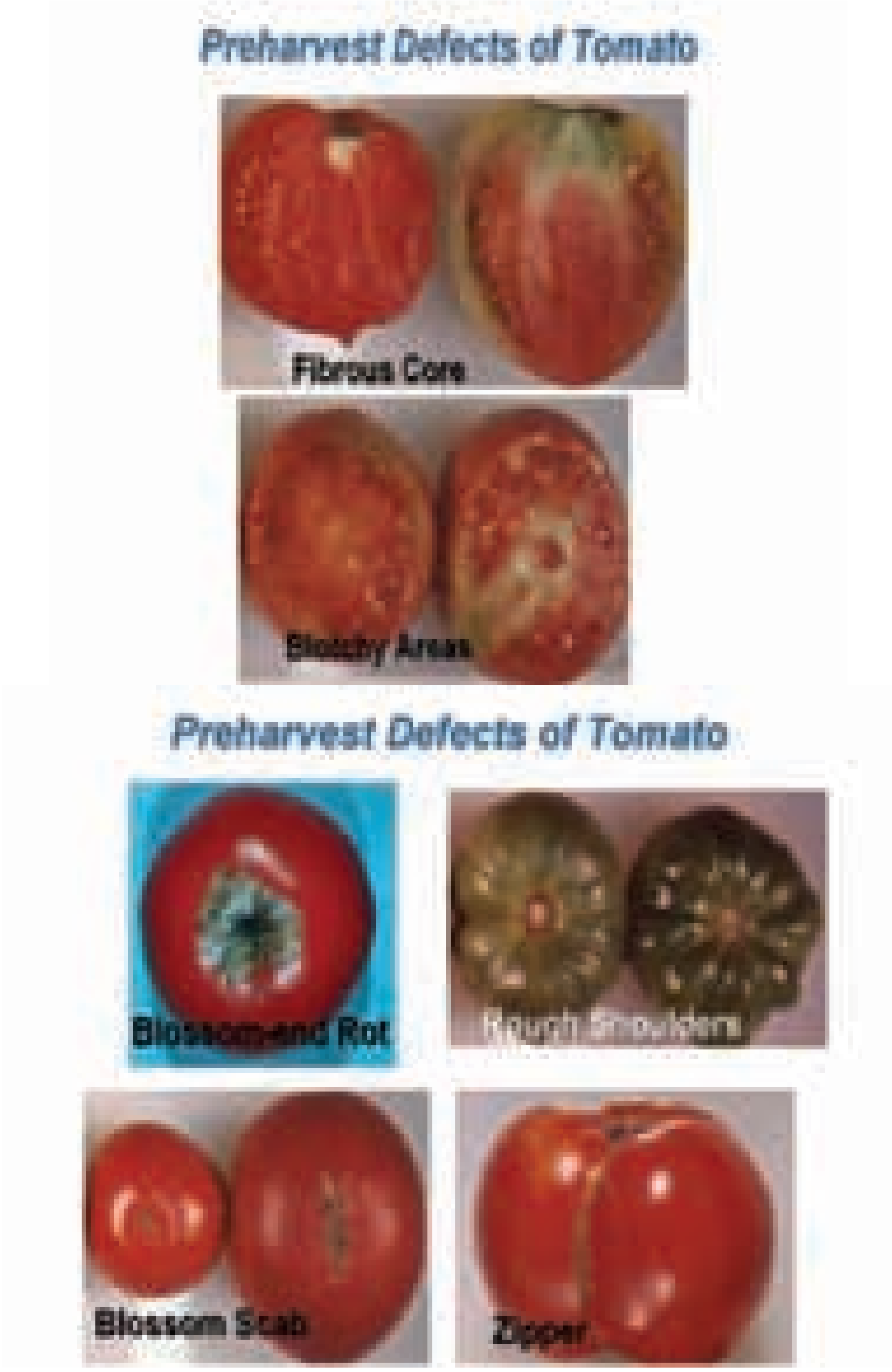


Figure 7. Preharvest defects in tomato (Source: Dr. A.A. Kader)

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# CHAPTER FOUR

# POSTHARVEST HANDLING OF SOME OTHER CROPS

# Almond (*Prunus amygdalus*)

Figure 1. Almonds

Almonds are rich in oil content; about 36 to 60% of kernel dry weight. About 90% of the fatty acids in almond oil are unsaturated, with the ratio of monounsaturated to di-unsaturated ranging from 2:1 to almost 5:1, which is important for human health. Almonds are non climacteric and because of their very low water content they are characterized by very low respiration rate, produce very low quantities of ethylene and can be maintained for a long period of time.

**Harvest**

Almonds are commonly harvested mechanically in big commercial operations using tree shakers. Nuts are dislodged from the tree by shaking and allowed to dry on the ground before being swept into windrows, picked up and transported to the huller. Some harvested nuts are dried after removal from the orchard, which is especially important if late season rains threaten a delay in harvest. Nuts must be dried to < 10% moisture prior to stockpiling. If limited huller capacity leads to stockpiling of nuts, they will likely be covered and subjected to periodic fumigation to limit insect damage. Early harvested nuts (hulls and kernels) contain more water than is acceptable and must be dried on the orchard floor for 1 to 2 weeks before they are picked up and hulled.

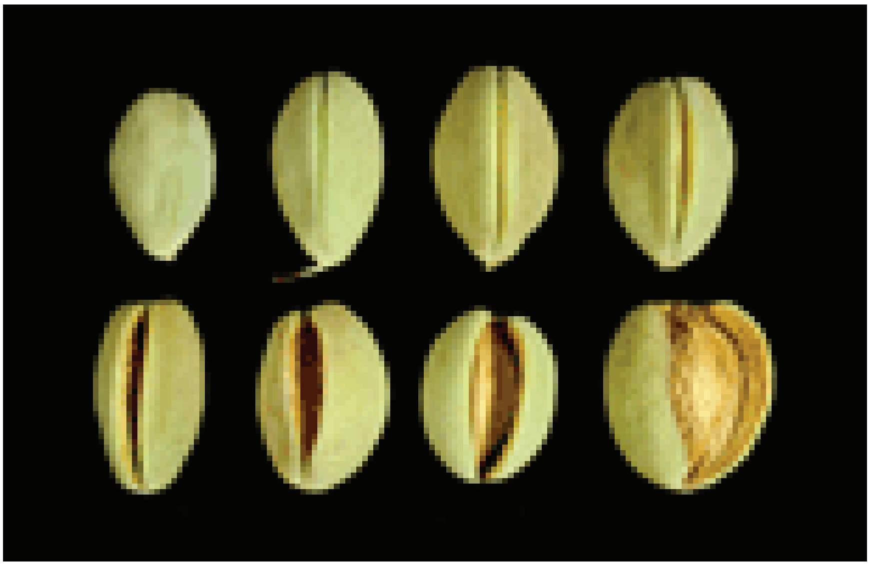

Figure 2. Shell opening stages (Source: U.C. Davis)

**Quality characteristics**

In-shell nuts should be characterized of an adequate shape and hardness of the shell as well as the brightness and uniformity of its color, freedom from foreign material and insect damage or decay. Shelled almonds should be free of shell debris and foreign material, and insect and decay. Kernel skin should be intact and should show no shriveling or discoloration. Nuts should not be doubled, split or broken, and without rancid flavor.

**Storage**

Almonds are characterized by very low metabolic activity because of low water and high fat content of the kernel, very low respiration rate and very low ethylene production; they tolerate low temperatures and extreme atmospheric gas concentrations (very low oxygen and very high $CO_2$), and therefore can be stored for a long period. It is important to maintain the low water content during storage. Safe moisture content for nuts to retard microbial activity is defined as a water activity of less than 0.7 at 25°C. Recommended storage relative humidity (RH) is 65%. Higher RH will increase water content and promote microbial growth. Cold storage of almonds is important to retard or minimize lipid oxidation and development of rancid flavor. In-shell almonds can be stored for up to 20 months at 0°C, 16 months at 10°C, and 8 months at 20°C, and shelled nuts can be stored for about half as long as nuts in the shell: about 6 months.

Almonds tolerate very low levels of oxygen and very high levels of $CO_2$ atmospheres. Low oxygen and elevated $CO_2$ atmospheres are beneficial to retard metabolic changes and to control insects. Flavor can be maintained for 12 months at 18 and 27.5°C in insect-controlling atmospheres of less than 1% $O_2$ and 9 to 9.5% $CO_2$.

**Physiological disorders**

Almonds need to be adequately dried immediately after harvest. Harvested nuts are often stockpiled and fumigated to control naval orangeworm prior to hulling and shelling. Temperatures in covered stockpiles that are open to the sun can reach 60°C. If nuts have not been dried to < 10% moisture in the orchard, or have been wetted by late-season rains, they should not be fumigated. The combination of elevated moisture and temperature leads to a problem called concealed damage, which is characterized by inversion of sucrose, lipid oxidation and internal kernel darkening. Elevated temperature alone does not cause the problem and forced air drying of rain-wetted kernels can prevent it, but wetting of freshly harvested almonds followed by heating can cause the problem. Premature sprouting indicated by the growth of the embryo between the unopened cotyledons, and rancidity are also potential problems that can be caused by improper storage conditions.

**Postharvest diseases**

Most diseases in almonds are initiated in the orchard. In-shell nuts are relatively protected unless the shell has been broken or penetrated by insects. The most serious fungi that attack nuts are *Aspergillus flavus* and *A. parasiticus*, which can produce aflatoxins that are both toxic and carcinogenic. Damaged kernels must be discarded prior to storage and low temperature and low relative humidity conditions must be maintained during storage. It has been found that the elimination of whole kernels with insect damage will reduce the number of whole kernels with excess levels (>1 ng/g) of aflatoxins.

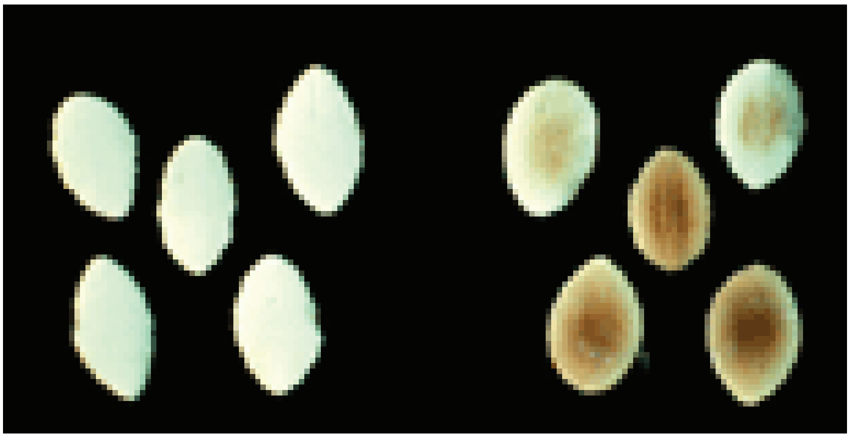

Figure 3. Almonds

**Insects**

Naval orange worm is the most important pest attacking almonds. Measures of control include fumigation with methyl bromide or phosphine, irradiation (about 30 kilo rad)and modified and controlled atmospheres (less than 1% $O_2$ and 9 to 9.5% $CO_2$).

Fig. (4): Almond mechanical harvesting

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# Cut flowers and ornamental plans

Figure 1. Diverse flowers (Source: Dr. Elhadi Yahia)

Flowers and ornamentals are very perishable products. Temperature has a profound effect on the rate of deterioration of cut flowers as well as on plant cuttings and potted plants. High temperatures cause increased metabolic activity, increased water loss and thus desiccation, and abscission. Short time exposure of cut flowers to temperatures above 20ºC can reduce their shelf life very considerably. Reducing temperature from 20 to 10ºC, reduces respiration of carnation 8 times, this indicates the necessity of cooling cut flowers as soon as possible after harvest.

Flowers are very sensitive to water loss which causes desiccation and wilting. Cut foliage and flowers can normally be rehydrated after harvest in a pulse solution or in vase solution. Water uptake by cut flowers depends on the quality and the composition of vase solution. Several factors affect the rate of absorption of water by various plants and flowers. However, most of the plants prefer acidic rather than neutral or alkaline solutions. The rate of uptake is often affected by plugging of the stem caused by embolism (air inside the stem) or bacteria which develops in the vase solution. To overcome this problem, stems are cut under running water or re-cut before putting in vase and application of bactericides in vase solution. As respiration rate of flowers is very high, sucrose and other types of sugars are used in vase solution as a supply for both the continuous development and respiration of the flowers.

Most cut flowers as well as many other ornamental plants are sensitive to ethylene exposure. Therefore, ethylene inhibitor, such as silver thiosulfate (STS), is commercially used as a postharvest treatment of flowers. Another chemical with high potential for reducing ethylene effects is 1-MCP.

**Maturity indices**

Maturity of flowers and ornamental plants is estimated based on the size, volume of the plant, height of cut foliage and the size and openness of the flower. The destination of the product has a great influence on the stage of harvest. For local market and short distance transport, flowers are harvested when the bud is slightly open.

**Harvesting**
Harvesting is done by hand using clippers, scissor or special knifes. Flowers should be harvested very early to avoid warm temperatures of the day. Harvested flowers are placed under shade in buckets or containers containing water. Then they are transported to the packinghouse for packing. Precautions should be taken to reduce leaf as well as bud damage.

**Cooling**
Pre-cooling is very important to reduce deterioration of cut flowers and ornamentals, and to prolong their life, and it is performed either for packed or unpacked flowers. Pre-cooling methods include room cooling, forced-air, vacuum cooling and package icing, with forced-air cooling being the most effective and the most commonly used. Flowers are kept in buckets containing a solution with low pH for re-hydration, or pre-cooled dry. The latter technique is very easy as water is not used, therefore handling is faster. The advantage of keeping harvested flowers in water is that water can contain a pulse solution composed of high concentrated sugar (20% sucrose) for 24 hours following harvest, which can extend the vase life very significantly.

The pH of the preservative solution should be below 5. Flowers with woody branches respond particularly well to low pH (3.5 is optimal), and some flowers (sunflowers, astilbe) respond well to a 10 minute pulse with a 0.02% detergent solution. Flower coolers during display should be kept at less than 5°C, and flowers should be placed in the coolers when not on display or being used for preparing arrangements. Most flowers should be held at 0 to 1°C. Chilling-sensitive flowers (such as anthurium, bird of paradise, ginger, tropical orchids) should be held at temperatures above 10°C.

Figure 2. Packing flowers

Figure 3. Flower package

**Grading and packaging**
All flowers and plants with external defects are discarded. Flowers are graded based on bud size, stem length and straightness, freedom of leaves from defects, insect attacks, physiological and disease disorders.

After sorting and grading, flowers are packed as bunches of a number of stems, depending on the type of flower. Flowers are packed in cartons with various sizes and the heads are placed at both ends of the carton for maximum space utilization. The flowers are immobilized to avoid or minimize damage during transport.

**Transport and shipment**
Flowers and ornamentals are transported in refrigerated trucks, or air transported to farther markets. Reducing the time between harvest and cooling associated with temperature management during handling and transport are essential for keeping good quality.

The vase-life of flowers that are stored even for a few days is closely correlated with their respiration during storage. Rapid cooling and proper refrigeration are thus essential to maintain quality and satisfactory vase-life of cut flowers and foliage. The recommended conditions for commercial storage and shipping of most cut flowers are 0 to 1ºC at 95 to 99% relative humidity. Although flowers are commonly held in water for short-term storage, better vase-life after longer storage is achieved by storing the flowers dry. Under these conditions, stable temperatures (to reduce condensation and *Botrytis* infection), and high relative humidity are essential. Flowers for longer-term storage are typically wrapped in newsprint (to absorb any condensation) and perforated polyethylene (to reduce water loss). Storage-life varies by species, but is typically less than 3 weeks.

**Physiological disorders**
**Chilling injury**. Some tropical plants such as anthurium, bird of paradise, some orchids, ginger and many foliage plants are injured at temperatures below 10°C. Chilling symptoms include darkening of the leaves and petals, water soaking of the petals, and, in severe cases, collapse and drying of leaves and petals. Special care needs to be taken with tropical flowers shipped in a mixed load. The flowers should be packed in plenty of insulating material. These flowers should not be pre-cooled. If they are to be shipped by refrigerated truck, they should be placed in the middle of the load, away from direct exposure to cooling air.

**"Topple" of tulips**. This disorder is a collapse of the scape associated with low calcium status of the flowers. Petal blackening in some red roses seems to be associated with inadequate calcium and perhaps boron nutrition.

**Postharvest diseases**
Flowers are very susceptible to diseases, their petals are fragile, and the secretions of their nectars often provide an excellent nutrient supply for pathogens. Transfer from cold storage to warmer atmospheres often results in condensation of water on the harvested flowers and disease infection. The most important disease in flowers is gray mold (caused by *Botrytis cinerea*), which can germinate wherever free moisture is present. Proper greenhouse hygiene management, temperature control, and minimizing condensation on harvested flowers reduce losses caused by this disease.

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# Olives (*Olea europaea* L.)

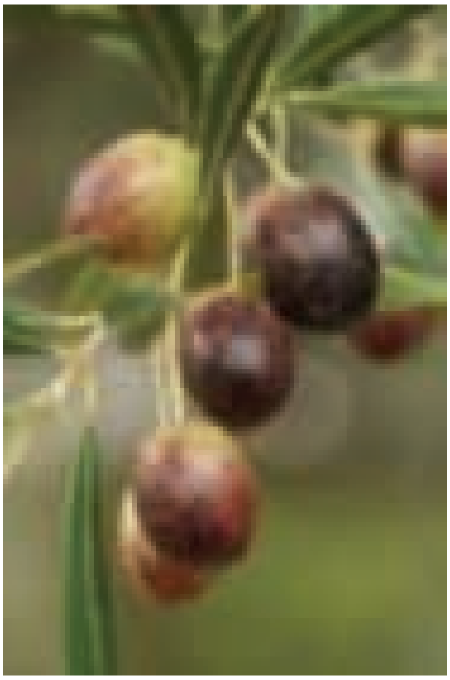

Figure 1. Olives

Olive fruit is non-climacteric and produces very little ethylene, with green olives producing less than 0.1 μL/kg/hr and black olives about 0.5 μL/kg/hr at 20°C, and intermediate respiration rate of about 40 to 80 mg $CO_2$/kg/hr at 20°C. Harvesting olives represents 50 to 70% of the total production labor cost and 30 to 40% of the gross returns from the crop.

**Quality characteristics**

Black olives should be of adequate color, free from defects, and with adequate oil content ranging from 12 to 25% depending on cultivar. Important quality characteristics for green olives include color, freedom from mechanical damage, shriveling, surface blemishes, scale and other insect injury, and decay. Fruit begin to lose moisture immediately after harvest, and therefore when harvested during hot weather it should be maintained in the shade while waiting to be transported. Sun-exposed fruit can get sunburn, and rough handling will cause bruises and grade reduction. Over-mature or badly bruised fruit frequently spoils during processing. To get the best return, fruit should be delivered to the cannery as soon as possible after harvest.

**Maturity indices and harvesting**

Olives for pickling are harvested either unripe and may remain green or ripe, when they are purple and turn black during pickling. Olives for oil extraction can be harvested from the straw-color stage through the black-ripe stage. Therefore, optimum harvesting stage is determined by the intended use of the olive, and its color and texture. Olive is generally considered mature if it exudes a characteristic white juice when squeezed. Green olive maturity indices include adequate size, even coloration with pale green and minimum of whitish spots (lenticels) through a straw color. Skin color is an important maturity index for black olives, and fruit usually reaches maturity (with black color) stage after about 3 to 4 months after the green stage. Some olives are sometimes harvested mechanically, especially with the aid of some chemicals (commonly ethylene releasing chemicals), and using tree shakers and catching frames

**Storage conditions**

Olives should be stored at 5 to 7.5°C and 90 to 95% relative humidity. For fresh green olives, atmospheres with 2-3% $O_2$ + 0-1% $CO_2$ can delay olive fruit senescence and softening for up to 12 weeks at 5°C, and 9 weeks at 7.5°C. However, lower $O_2$ concentrations (less than 2%) can cause off-flavors, and higher $CO_2$ concentration (higher than 5%) may increase severity of chilling injury if olives are stored below 7.5ºC. Black fresh olives can be kept in 2% $O_2$ at 5°C for up to 4 weeks.

**Physiological disorders**

**Chilling injury**. Olive fruit are sensitive to chilling injury at temperatures less than 5°C. Chilling injury becomes visible on olives stored for more than 2 weeks at 0°C, 5 weeks at 2°C, or 6 weeks at 3°C. Chilling symptoms in 'Ascolano', 'Manzanillo', 'Mission', and 'Sevillano' fruit are a slight, tannish to brown discoloration which develops in the flesh adjacent to the pit, and over time, the discoloration becomes more intense and progresses through the flesh into the skin, at which time the olive has the appearance of having been boiled.

**"Nailhead"**. Appears on olives kept at 10°C for more than 6 weeks or at 7.5°C for more than 12 weeks. This disorder is characterized by surface pitting and spotting, and results from death and collapse of epidermal cells, creating air pockets underneath fruit skin.

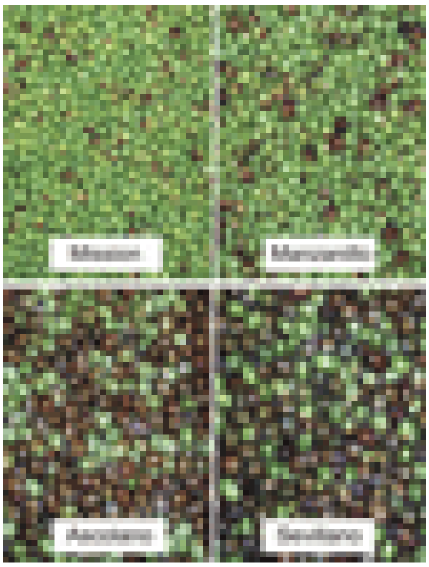

Figure 2. Olives maturity grades (Source: U.C. Davis)

**Postharvest diseases**

Postharvest diseases occur if olives have been chilled at temperatures below 5°C, mechanically damaged, not cooled promptly after harvest to 5 to 7.5 °C, or exposed to undesirable atmospheres with more than 5% $CO_2$ and/or lower than 2% $O_2$.

**Insects**

Olive fruit fly (*Bactrocera oleae)* is a quarantine pests in some countries, and therefore appropriate pre-harvest and postharvest treatments should be sought if fresh olives are to be exported to one of these countries.

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# Peanuts (*Arachis hypogaea* L.)

Figure 1. Peanuts

**Quality characteristics**
Good quality shelled peanuts should have adequate size, be free of misshapen or under-developed kernels and off-odor or flavor. Raw peanuts should be surrounded by a tan, pink or red- colored seed coat (testa) that fully encapsulates the seed, and the interior color of each half-seed should be ivory. Moisture content for in-shell peanuts should be less than 10% to prevent mold growth. Peanuts should contain 7 to 10% moisture prior to shelling to reduce splitting and kernel breakage during milling, and after milling 7% or less. Peanuts marketed without seed coats (blanched) should have an ivory colored raw kernel. Roasted peanut kernels should be light-yellow in color, free of external oil, with less than 6% moisture and free of dark-colored kernels. Peanuts contain 0.02 to 1.79 µg/g of resveratrol, a compound suggested being important for health. Fatty acid composition of peanut oil is predominantly oleic and linoleic acid, and peanuts with a high oleic:linoleic acid ratio are less susceptible to oxidative deterioration and off-flavor (rancidity).

**Maturity indices**
Mature peanut contain brown inner hull and pink to red seed coat. For example, at optimum maturity 75-80% of the inner hull becomes is brown in "Runner" and "Spanish" peanuts.

**Packaging**
Raw in-shell peanuts are typically stored in flat, ventilated warehouses or grain bins in bulk or, less commonly in about 20 Kg burlap bags, for a week to 10 months prior to shelling. After shelling, raw peanuts are often shipped in bulk containers, but may be packaged in burlap or nylon tote bags of various sizes.

**Storage conditions**
In-shell peanuts dried to about 7.5% moisture can be stored at 10°C for up to 10 months without significant quality loss. High losses in milling quality may occur if peanuts are dried to below 7% moisture or if kernel temperature is less than 7°C during shelling. Peanut moisture contents should not be more than 10% to prevent mold growth. Adequate ventilation during storage is important, with at least one air change every 3 minute. Raw shelled peanuts can be maintained for at least 1 year at 1-5°C with moisture contents less than 7%, or for 2 to 10 years at -18°C and less than 6% moisture. Storage at 1-5°C and 55-70% relative humidity will maintain peanut moisture content at 7 to 7.5%. Moisture condensation should be prevented upon removal of raw shelled peanuts from refrigerated or frozen storage. Peanuts tolerate atmospheres with extreme

concentrations of gases, and therefore low $O_2$ storage can be used to delay the development of rancid flavor and to control insects. High $CO_2$ atmosphere can reduce the growth of *Aspergillus flavus* in short duration storage of high moisture, non-cured peanuts. Peanuts are normally marketed at ambient temperature conditions, but use of low $O_2$ (especially in the packages) and preventing excessive exposure to light and moisture is recommended.

**Postharvest pathology**

The most serious pathological problems in peanuts are caused by molds and fungi, and therefore the presence of mycotoxins is of particular concern. Peanuts with visible *Aspergillus flavus* mold, or those containing more than 15 ppb aflatoxin, may not be used for edible purposes. Four aflatoxins can be found in contaminated peanuts, designated as aflatoxin $B_1$, $B_2$, $G_1$ and $G_2$. Aflatoxins $B_1$ and $B_2$ are metabolites of *Aspergillus flavus* and all four aflatoxins may be produced by *Aspergillus parasiticus*. A fifth mycotoxin which is somewhat less toxic than aflatoxin and is produced by *Aspergillus flavus*, other *Aspergillus* species, and several species of *Penicillium,* is cyclopiazonic acid. Pre-harvest conditions favoring aflatoxin contamination are high temperatures and drought stress during the last 3 to 6 weeks of the growing season. Peanuts for human consumption must be free of visible *Aspergillus flavus* mold, and should contain less than 15 ppb (parts per million) aflatoxin. Late season irrigation may be effective in reducing aflatoxin contamination. Storage conditions to reduce mycotoxins problems include maintenance of a moisture content of less than 7.5%, prevention of rehydration during storage, use low temperature during (1-5°C).

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# Tamarind (*Tamarindus indica* L., syns. *T. occidentalis* Gaertn.; *T. officinalis* Hook.)

Figure 1. Tamarinds

Tamarind fruit is a good source of calcium, phosphorous, and iron, excellent source of riboflavin, thiamin, and niacin, but contains only small amounts of vitamins A and C. Tamarind is considered to be both the sweetest and most sour of all fruits.

Tamarind is a non-climacteric fruit, and the maximum $CO_2$ production occurs 4 weeks after fruit set, and then gradually declines.

Figure 2. Tamarinds pods

**Quality characteristics**
Both green immature and brown, ripe pods are normally marketed when they reach 5 to 20 cm long.

**Maturity indices and harvesting**
Tamarind fruit take about 8 months from fruit set to harvest, and as pods mature, skin develops into a brown, brittle shell, the pulp turns brown or reddish-brown, and seeds become covered with dry and sticky pulp. When fully ripe, the shells are brittle and easily broken. Mature fruit can be left on the tree for more than 6 months after ripening without significant spoilage; however birds and insects become pests. Fruit should be harvested when the moisture content is less than 20% to facilitate separation of the shell from the pulp. In humid climates, fruit are readily attacked by beetles and fungi, and should therefore be harvested before they are fully ripe.

Fruit can be pulled off the peduncle or cut using scissors. Fruit for immediate processing are harvested by pulling pods away from the stalk. Some can be harvested by shaking the branches, leaving the remaining fruit to fall naturally when ripe. Dry, ripe fruits are easily cracked, and the pulp and fibers separated from the broken shell.

**Storage conditions**

Tamarind is characterized by a long storage life because of the low water content, and high soluble solids content to titratable acidity. It can be stored either with the skin, or as a separated dry pulp, and tightly packaged pods can be stored at 20°C for several weeks. The pulp of mature tamarind is commonly compressed and packed in palm leaf mats or plastic bags and stored at 20°C for a significant period when processed into paste. It can be frozen and stored for 1 year, or refrigerated for up to 6 month. During storage, the dry, dark-brown pulp becomes soft, sticky, and almost black. The pulp can be stored for a longer period after drying or steaming.

**Postharvest diseases**

Tamarind fruit are usually very tolerant to pathogens and insects because of low water content, high acid and sugar content, and high polyphenol content in the peel. However, there are occasional incidences of scab, and ripe fruit can be susceptible to mold, insects and birds.

**Insects**

Various weevils and borers can infest the ripening pods or stored fruits. Tamarind beetle (*Pacymerus* (*Coryoborus*) *gonogra*) and tamarind seed borer (*Calandra* (*Sitophilus*) *lineris*) can infest ripening pods and persist in the stored fruits. The rice weevil (*Sitophilus oryzae*), rice moth (*Corcyra cepholonica*), and fig moth (*Ephestia cautella*) can infest fruit in storage.

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# CHAPTER FIVE

# MARKETING

# Basics of Fresh Produce Export Marketing

## Introduction

The fresh produce market has changed markedly over the last 15 years. Shifts in consumer demand, technological change in production and marketing, and retail consolidation have altered the traditional market relationships between producers, exporters, and retailers. Consumers are eating more fresh produce, purchasing a wider variety year-round, and demanding more convenience. Information technology has introduced efficiencies throughout the supply chain, reducing production and marketing costs. Retail consolidation has occurred rapidly as large supermarket firms have merged or been acquired. Mass merchandisers and warehouse club retailers are selling an increasing volume of food products with low-price strategies. Fresh fruits and vegetables sold to restaurants, fast-food outlets, and other foodservice operators have grown to account for more than half of all retail produce sales.

To coop with these new trends and building an effective fresh produce export strategy, fresh produce growers and exporters should be able to understand those trends to be able to compete effectively in this challenging environment. To build successful export strategy, fresh produce exporters must understand the following aspects:

1. Understand the fresh produce export and marketing trends and dynamics
2. Assess the potential of the export opportunities for your product
3. Design appropriate market entry strategy

## Understanding the Dynamics of Produce Markets

International trade in fruits and vegetables has expanded more rapidly than trade in other agricultural commodities, especially since the 1980s. Although fruits and vegetables now claim a significant share of world agricultural trade, little research has been done on the global patterns and dynamics of this trade. The category "fruits and vegetables" encompasses a great variety of commodities, each with its own characteristics and institutions. Despite this variety, some trends, and the forces behind them, appear to apply to a large number of fruits and vegetables.

Rising incomes, falling transportation costs, improved technology, and evolving international agreements have led to substantial growth in the volume and variety of fruits and vegetables traded globally. Three regions— the European Union (EU), the North American Free Trade Agreement (NAFTA) area, and Asia (East, Southeast, and South)—are the major destinations, as well as the major sources of supply, for this trade. All three regions depend on Southern Hemisphere countries for imports of juices and off-season fresh fruits, and on equatorial regions for bananas, the leading fresh fruit import (figure 1).

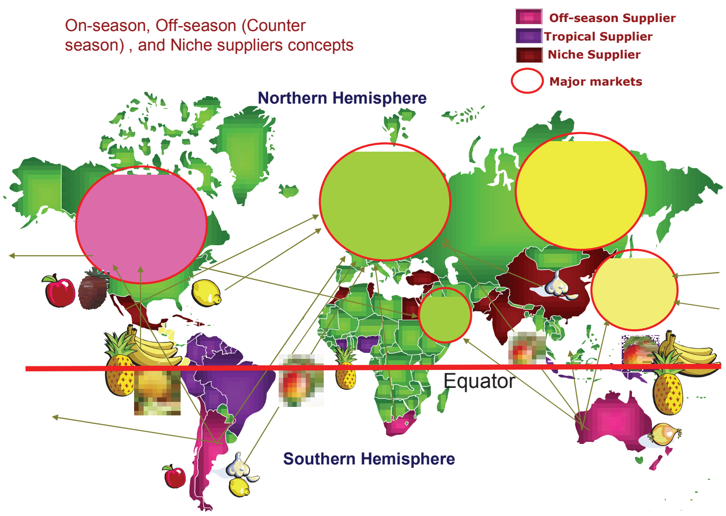



Figure 1a. Fresh Produce World: Overall Production and Trade

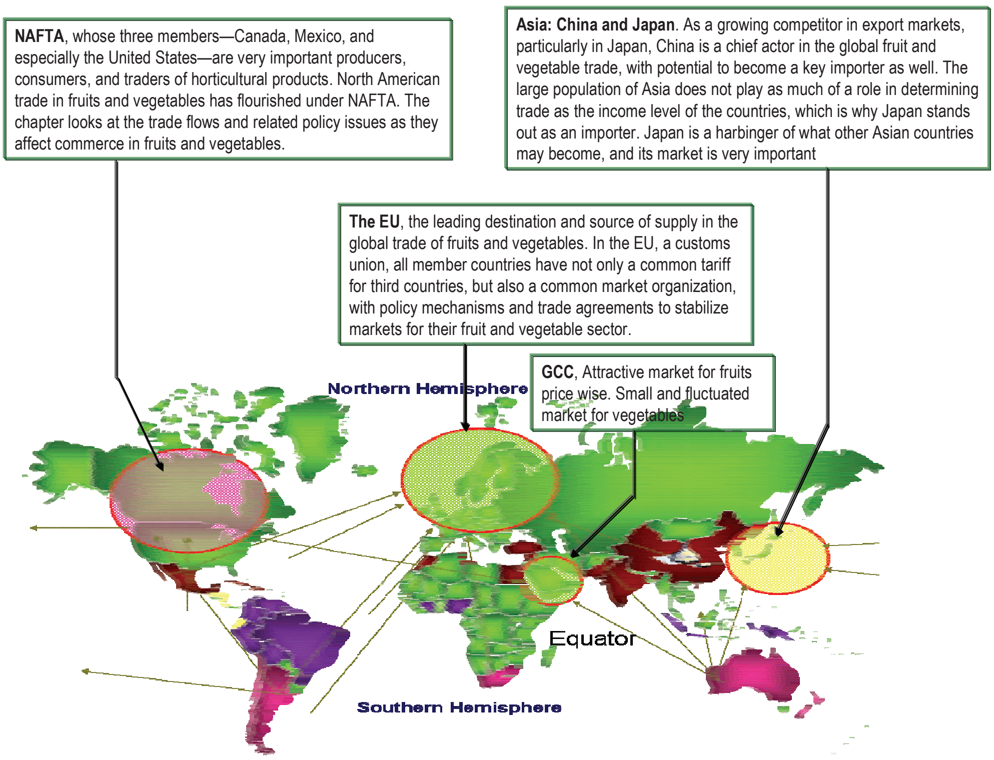



Figure 1b. Concentration in the target destinations of the fresh produce

The EU is both the leading destination and source of supply in the global fruit and vegetable trade, accounting for nearly half of the world's imports and more than 40 percent of the exports. Most EU trade, however, is intraregional, except for fresh fruit, for which extra-EU trade is slightly larger than intra-EU trade. In addition, a substantial share of these extra-EU imports comes from geographically proximate partners or ex-colonies under preferential trade agreements.

Intraregional trade is also important for NAFTA, particularly for fresh vegetables, which are mostly intra-NAFTA commodities. For other commodity groups, however, NAFTA members import heavily from the Southern Hemisphere and send sizeable exports to Asia. Trade with the Southern Hemisphere and equatorial regions is mainly in imports of juices, off-season fresh fruits, and bananas. During 1999-2006, nearly 60 percent of fresh fruit and 45 percent of juice imported by NAFTA originated from Southern Hemisphere countries and equatorial regions.

Fresh fruit Fresh vegetable

Figure 2. Destination of fruits and vegetables exported by the world's 30 top exporters

Source: USDA, ERS, Global Trade Patterns in Fruits and Vegetables.

During the same period, Asian markets, mainly in East Asia, accounted for 20 to 30 percent of NAFTA exports. Asian trade is dominated by China's exports and Japan's imports. Most of China's exports were to neighboring Asian markets, with Japan the leading market for China's horticultural exports. Since the 1990s, China has sharply increased its presence in Japan's import market for fresh and frozen vegetables.

While intraregional trade still dominates global trade patterns in fruits and vegetables, extra-regional trade has become more important in the past decade. Most of it involves global north-south trading, due mainly to the countercyclical seasons of the two hemispheres. Tariff structures in the EU and NAFTA tend to reinforce this pattern. Asian trade has also become much more important since the mid-1980s as incomes and populations have grown and policies changed. A big exception to the seasonality of produce traffic is bananas, the most traded of all fruits and vegetables. Continuous-growth equatorial regions account for a substantial share of global banana exports.

These major trading patterns exist for a variety of reasons, which can be loosely grouped as supply, demand, institutional, and other factors (figure 2). **Supply side** factors include such fundamental aspects as climate, location, technology, costs, factor endowments, and infrastructure, among others. The ability to maintain quality through technology has enabled the emergence of a global market, for example, by allowing tropical fruits to be introduced into markets previously unreachable.

**Demand-side factors**, which include rising incomes and the creation of a middle class that demands quality produce in all seasons and is willing to pay, have had major consequences for trade. The cheaper prices and better quality resulting from lower tariffs and improved technology have also increased demand. High-income countries like the United States, EU members, Japan, and Canada, account for the overwhelming majority of the fruit and vegetable trade, as well as for its growth. The EU and the United States, in particular, are the largest traders in the global market of fruits and vegetables. The Common Agricultural Policy in the EU and the trade liberalization measures in NAFTA are two examples of **institutional factors** that play a role in the patterns of global trade in fruits and vegetables.

**Globalization** of the fruit and vegetable trade has made fresh produce accessible to consumers around the world, overcoming seasonality and smoothing price fluctuations. High income-growth rates in developing countries portend higher rates of fruit and vegetable consumption and trade in the future. In the meantime, developed countries will dominate global consumption and trade of fruits and vegetables, not only because of their high income levels but also because of consumers' increasing concerns about healthy eating, which tend to increase fruit and vegetable intake in their diets. The United States is well placed to take advantage of the potential for greater horticultural trade, both as an importer and as an exporter, because of its income level, access to advanced technology and transportation, and trade agreements that allow for the freer flow of products around the globe.

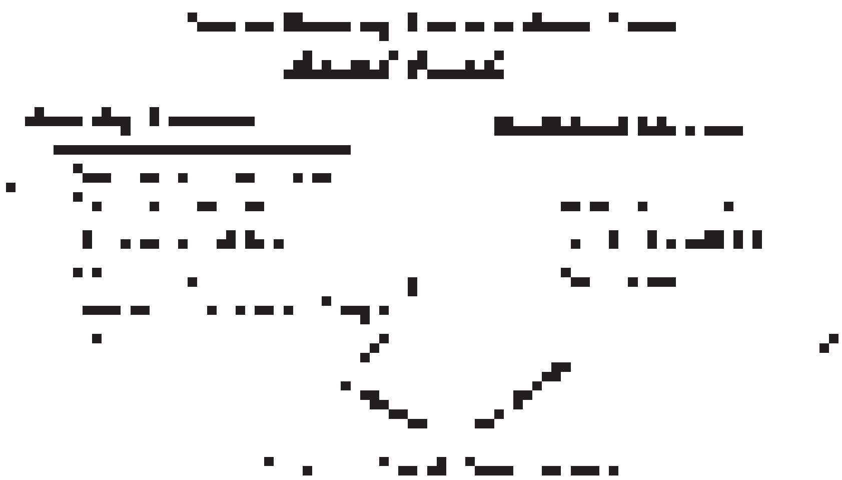


Figure 2. Supply-Demand factors influencing the fresh produce global trade

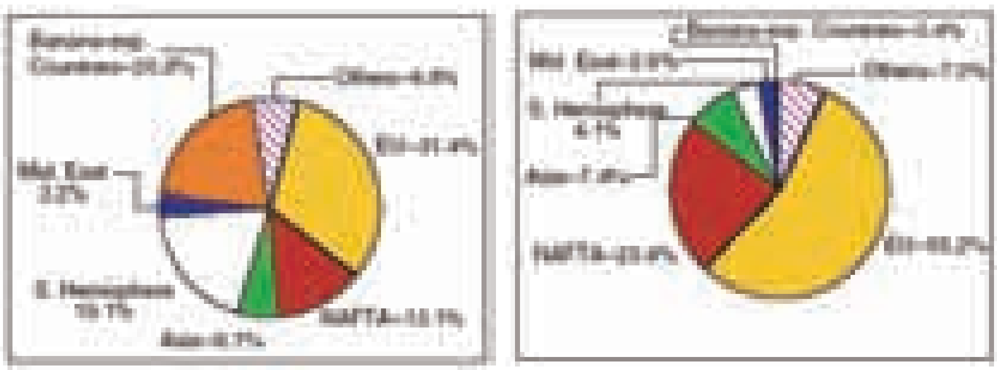
## Southern Hemisphere Countries: Important Suppliers for Off-Season Fresh Fruits

**The opportunity of the WANA region exporters is to focus on filling the gab between on-season suppliers and off-season suppliers. Careful identification of the market windows is crucial for export success**

With a crop production cycle opposite to that of the Northern Hemisphere, the Southern Hemisphere exporters, whose summers come during Northern Hemisphere winters, play a vital role in making the year-round supply of fresh fruits possible. These countries have taken advantage of the seasonal differences to expand their exports, particularly for many temperate-climate fruits. The market for off-season fruit imports in the Northern Hemisphere continued growing in the 1990s, after a fast expansion in the 1980s, as several Southern Hemisphere countries boosted their fruit production.

During 1999-2006, Southern Hemisphere fresh fruit shipments accounted for 19 percent of the value purchased by the world's top 30 fresh fruit importers. Two major destinations for these fresh fruit exports were the EU (43 percent) and NAFTA (24 percent, mainly to the United States). Other important destinations included Asia (16 percent, mainly to East Asia) and South America (8 percent).

Thus far, no country in the region has succeeded in topping Chile as the region's leading exporter; Chile accounted for nearly 35 percent of the value of fresh fruits exported by the Southern Hemisphere countries in 1999-2006.



Fresh fruit Fresh vegetable

Figure 3. Origin of fruits and vegetables imported by the world's 30 top importers

Source: USDA, ERS, Global Trade Patterns in Fruits and Vegetables.

Next to Chile is South Africa, chiefly targeting the EU and accounting for 70 percent of U.S. imported grapes during 1999-2006, Chile also accounted for virtually all U.S. imports of fresh plums, peaches, and cherries. In comparison, three-fourths of Chile's fresh fruit exports to the EU were grapes, apples, and pears.

During 1999-2006, more than half of the fresh fruits exported by the Southern Hemisphere countries were temperate-climate fruits such as grapes, apples, and, to a much lesser degree, pears. About two-thirds of apples exported by the Southern Hemisphere countries came from Chile and New Zealand, while Chile and Argentina were the dominant suppliers for grapes and pears. Geographic proximity is particularly important for those Southern Hemisphere countries that export fresh fruits to Asia and South America. For example, the Asian market is important to exporters in Australia and New Zealand, who shipped almost no horticultural products to South America, while South America is a more important market than Asia for Argentina, Brazil, and Chile.

## The Drive to Globalize Markets in Fruits and Vegetables

Year-round consumer demand for high-quality fresh fruits and vegetables is a critical influence in global changes in the fruit and vegetable trade. Without trade in fresh fruits and vegetables, consumers in temperate climates would face long winters with very limited supplies of fresh produce. While some fresh crops can be stored for a few months, such as apples and potatoes, more perishable products like strawberries and tomatoes would be available in much smaller quantities, if at all. Variety is also important. Without trade, temperate countries would not have tropical fruit such as bananas and tropical countries would not have deciduous fruit like apples.

Even when weather or biology is not a barrier to production in a particular country, there are many other economic reasons for trade in produce. In some cases it is cheaper and more efficient to produce a commodity in a foreign country, so production shifts geographically. For example, much of the European fresh green onion and artichoke supply are now imported from WANA countries because the cost of labor is lower in WANA countries and preparing these products for market is labor intensive; green onions are formed into bunches by hand and cut by hand. Some EU firms have shifted operations to North Africa because of the lower labor costs, and Northern African firms have also developed their own industries.

Technological developments have changed the profitability of exporting certain produce items and contributed to the growth of trade. For example, transportation advances have made it cost-effective to ship more perishable products to the EU markets from abroad. Improvements in communications have made these international transactions easier.

**The partnership agreement between several MENA countries is expected to enhance the trade between those countries and the EU market.**

The streamlining of phytosanitary barriers through technology has opened new markets for many products. Declining trade barriers, including bilateral and multilateral trade agreements, harmonization of sanitary and phytosanitary regulations, and dispute settlements under the auspices of the World Trade Organization (WTO), have also fostered more trade. Despite the improvement in the overall trade environment for fruits and vegetables, there are still high tariffs and other non-tariff barriers to trade.

## Implications of Globalization for the Produce Industry

With fewer constraints and lower transaction costs, firms can design strategies for optimization of sourcing on a global level. Being a player in an international arena requires more resources than being a player in a national market. Some exporters will be better able than others to adapt to the challenges.

Several types of firms handle fresh produce imports. Traditional importers have no domestic production ties and may or may not have production ties in the country of origin. They are mainly marketers. Some importers are the marketing arms of large producers in other countries. Others are large multinational firms with brand name recognition such as Del Monte, Chiquita, and Dole. Some large grower/shippers have also developed import ties to augment their domestic production. Many of these firms have expanded the number of countries from which they import to ensure year round supplies and the wide range of products that retail buyer's desire.

Firms have several options in using foreign production to help expand their season. For one, a firm may grow a product on its own farms in a foreign country for sale in the export market. This kind of investment provides a high level of control over the quality of the product. A firm might also have a joint venture with a firm in a foreign country to produce a crop to be sold in the export market. In some cases, firms may merge with a foreign supplier. Many shippers and grower/shippers also market for foreign growers and charge a sales commission. Some grower cooperatives have foreign members who must also meet the organizations' domestic production standards.

Suppliers must develop relationships with reliable foreign growers to provide produce. A high level of integration is essential for success in a multi-country operation because of problems of coordination and quality control. Suppliers may travel frequently to foreign production regions to cement the relationship with their growers. The suppliers may send agronomists to check on production and crop conditions. Some firms have staff living in foreign countries.

The stakes are high for procuring products from another country. If the product does not arrive on time or has quality problems and cannot be sold, the supplier may not have adequate supplies for its customers, a serious problem in the competitive produce industry. On the other hand, selling a substandard product may damage the firm's and the supplying country reputation. The stakes are also often high for the foreign producer. Many foreign countries have very specialized produce industries, geared almost exclusively towards exports. If products are not acceptable in the export market, the producers often have few alternative markets and must sell at lower prices. For example, some of the products grown in Mexico for export to the United States, such as bell peppers, cherry tomatoes, and eggplant, have virtually no domestic market.

The example of grape grower/shippers illustrates some of the issues to be considered in importing grapes from other countries. (These same issues are relevant for other types of produce importers.) Grower/shippers have several options when confronted by the increasing importance of imports. They can maintain the traditional model of growing for their season and marketing their own output and perhaps that of some of their neighbors. Alternatively, some South African grape firms have become year-round suppliers by expanding beyond their traditional Southern Hemisphere base to supply grapes from WANA countries, India, and Pakistan. Many retailers prefer to do business with a firm that can supply all their grape needs on an annual basis instead of shifting from firm to firm as different production areas come into season. Operating on a year-round basis allows firms to gain economies of scale and spread fixed costs over a large volume of the product. Most South African grapes are shipped from December to April, leaving facilities idle for half the year if a firm sells only domestic grapes. Year-round supply strategies also benefit shippers by maintaining their marketing presence with buyers all year. However, coordinating supplies from other countries demands more capital and risk-bearing capabilities than are usual in domestic marketing alone. Not all firms have the wherewithal, or the desire, to become international grape suppliers.

### Impact of Retail Consolidation on the Produce Industry

Consolidation in the retail sector, both in the EU and in many import countries around the world, also has an impact on the supplier/buyer relationship. Large retailers desire large volumes of consistent products to provide uniformity across all their stores, which may be more easily supplied by larger shippers. Recent research has shown that retailers buying a select group of produce items acquired 91 percent of the volume from their top four suppliers.

Retailers are also increasing their demand for differentiated products. For example, table grapes can be marketed in many different ways to appeal to a wide customer base. A retailer may want an grapes for which a specific firm provides third-party certification for compliance with good agricultural practices or a particular type of packaging, an unusual variety, a special kind of storage, or a particular production system, such as organic. Product differentiation has an important impact on international trade because it requires increased coordination between shipper and buyer as shippers provide more specialized products for particular buyers.

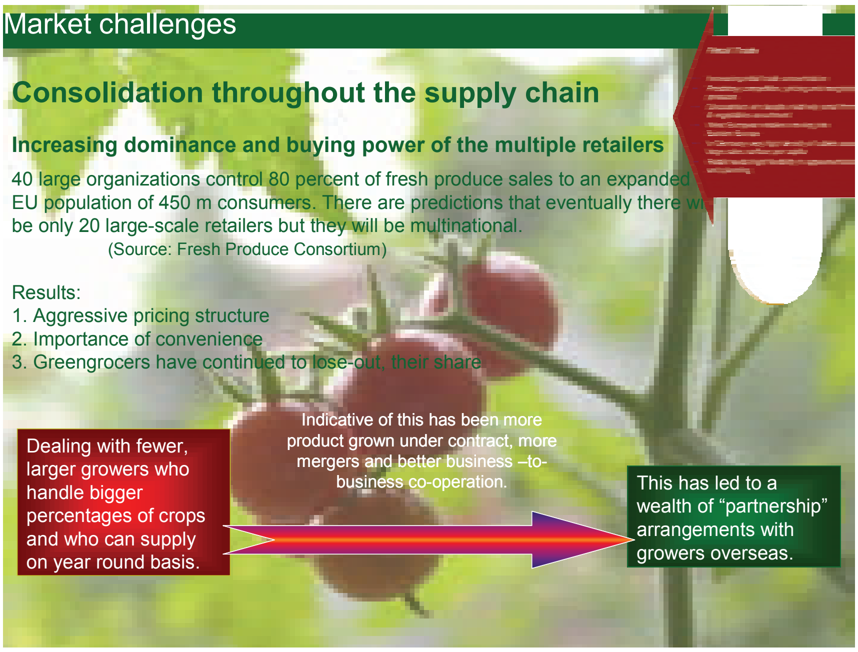



Figure 4. consolidation on retail level is major challenge for small suppliers


Figure 5. Supermarkets dominates the fresh produce retailing in the target export markets

Globalization of markets is likely to continue as the basic factors of supply combine with technological developments and lower trade barriers to meet consumer preferences to shape and create trade flows. Innovative financial arrangements across borders and flexible global sourcing have combined to provide markets with high quality and a wide variety of fresh produce year round to consumers around the world.

**Fresh Produce Traceability systems;**

Consumer safety has become a priority issue for the fresh fruit and vegetables supply chain. Tracking and tracing of goods has therefore become increasingly important and is now to a certain extent legally required by the EU. Tracking is about the location of products, and tracing is about where the products come from. Traceability systems are used for accurate and timely identification of products, their origin, location within the supply chain and efficient recall. The flow of products along the supply chain should be recorded so that the origin of any problem can be located and all possibly affected products can be recalled. Tracking and tracing is also part of meeting consumers ' expectations and restoring or maintaining their confidence in the safety and quality of purchased products.

Traceability is becoming a major issue for exporters when supplying European importers serving multiple retailers. This means that the grower/exporter has to put extra effort into communicating information with the rest of the supply chain. The exporter should always discuss the matter of traceability with his importer and choose the traceability standard most suitable for the intended export market.

## Building an effective fresh produce export strategy

### Market audit

Market audit is crucial for developing effective fresh produce export strategy. Market research assists the exporter in identifying market opportunities, suitable sales channels and relevant information on the market and the external environment. Market research should cover many aspects that can be categorized into four major components. To build the export strategy the exporter should answer the question: is there profitable market for my product? If the answer is yes, then the exporter should move to the next question: how can I access this market? The first question regarding the existence of the export market should cover two major types of export related information, namely the market size and trends and the prices and profitably in the target market. Market access information includes all aspects related to the market entry constraints. The following figure (figure 6) summarizes the types of information necessary for an exporter to be able to build successful fresh produce export strategy.

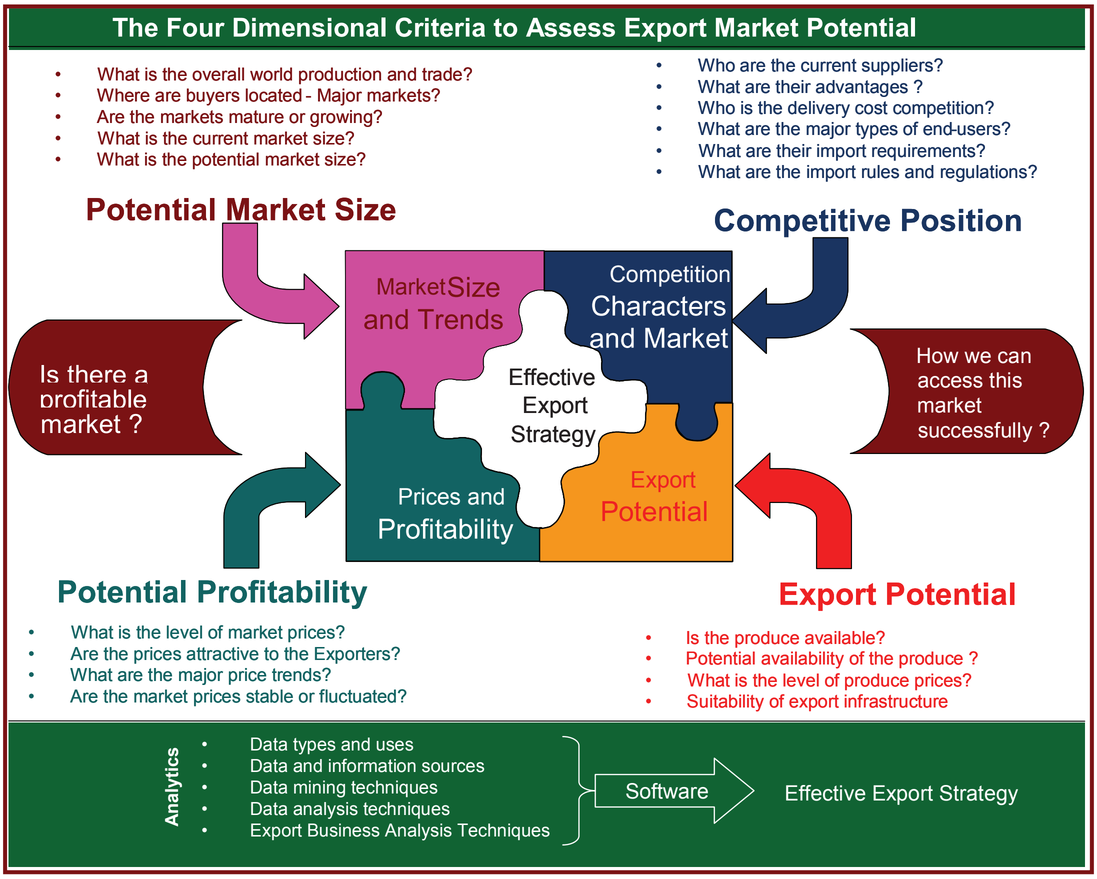



Figure 6. Necessary information for an exporter to be able to build successful fresh produce export strategy

For identifying the most suitable export markets, an exporter needs to understand the developments and trends of the European fresh fruit and vegetable market. A first step can be the analysis of market research data. It is important to assess the implications of important trends such as health food, convenience, and interest in exotics for your products as they may represent opportunities for you. The large overall trends that can be observed in many EU countries are interesting since they imply a large market. But small, national trends (such as ethnic food) may provide an attractive niche market as well, particularly for starting or small-scale exporters. Some of the other questions that need to be answered before entering a new market are:

- What is the (estimated) market size for your potential export products? Try first to focus on your product group, then on your specific products.

- How has total market volume developed during the past 3-5 years? If there is no specific information on your products or varieties, then try to obtain information on the development of markets for related products.
- How have imports developed over the past 3-5 years?
- How competitive is the market for your product in terms of supply and competitor countries and suppliers?
- What is the window of opportunity for your products in a specific market? During which period of the year?
- What are the prices and price developments?
- Are importers and potential business partners in the EU interested in new suppliers of your particular products?

The market research should inform the company about the largest markets for its product, attractive niche markets, the fastest growing markets, market trends and outlook, market conditions and practices, and competitive firms and products. Based on all this information, a company can then develop the most promising product-market combinations.

**Major sources of market information for the EU market are:**

- **For general information and a list of the European national trade statistics bureaus, you can use the EU statistics bureau Eurostat: http://europa.eu.int/comm/eurostat**
- **Internet site with daily news about the market and useful trade information in English: http://www.freshplaza.com**

### How to estimate the potential Export Market for Your Products

The methodology to set priorities and screen export markets consists of four types of prioritizing indicators and screening criteria:

(A) Potential market size
(B) Potential profitability
(C) Competitive position
(D) Export potential.

Inside these four general types, the methodology develops quantitative indicators for ten specific prioritization and screening criteria. In developing the ten indicators the methodology also develops and utilizes the specific items as intermediate.

The overall prioritization and screening concepts, (1) product/market size, (2) profitability and (3) competitive position are quantified by the methodology as ten specific prioritization indicators as follows:

**A. Potential Market Size**

1. Total Market Size (total consumption as indicator of consumer eating preferences)
2. Import Market Size (seasonal imports as indicator of capacity to self-supply)
3. Profitable Demand Market Size during the Seasonal Export Window

**B. Potential Profitability and Value Added**

4. Profit and Margins per Metric Ton
5. Total Profits for Profitable Demand Volumes

**C. Estimated Competitive/Comparative Position**

6. Seasonal Position
7. Transport Cost Position
8. Wage Rate Position
9. Landed Cost per Unit

**D. Export Potential**

10. Production season and geographical position (Country exports to the potential export markets and the capability of delivering high quality products)

***A. Potential Market Size***

The objective of the market size screening criteria and quantitative indicators is to give priority to the largest volume opportunities among the potential markets analyzed. Three separate, but related, market size concepts are developed in the three component screening criteria and quantitative indicators.

| Screening criteria | As an indicator of |
|---|---|
| 1. Historical consumption volumes and trends | Consumer eating patterns and preferences |
| 2. Historical import volumes and trends by season | Capability to self-supply, import dependence, and capacity to fund imports |
| 3. Profitable Demand | Unsaturated potential import volumes during the seasonal export window. |

**1. Total Market Size**

Total consumption, including recent total and per capita volumes and long term trends, will be used as indicators of consumers' eating preferences and patterns. The intent of this indicator is to prioritize those markets where large consumption gives evidence of established and stable consumer product awareness and eating pattern dependence.

**2. Import Market Size**

Seasonal import volumes during recent years, and longer term trends, will be used as indicators of three market size concepts:

- The capability of the country to self-supply its consumption demand
- The demonstrated capability of consumers, marketers and importers and related infrastructure to handle, store, transport and pay for imports to meet local production gaps.
- The demonstrated capability of the economy to fund the foreign exchange requirements of these imports.

**3. Profitable Demand Market Size**

The Profitable Demand concept of market size is defined as the volume of a particular product which a specific country market has consumer demand capacity to import above recent year levels during the seasonal export supply window at prices to exporters above their break-even cost level. The **Profitable Demand** concept develops a quantitative estimate of the volume of unmet consumer demand at, or above, prices which would be break-even or better for the exporters during the seasonal window when WANA countries can supply to that market.

The profitable demand concept and methodology address the issues that quantity and price interact and that a single large supplier, and/or a number of smaller but significant suppliers can and will affect prices with the volumes they supply. This methodology provides a relatively simple method for estimating the seasonal import volume and unmet volume demand issues from the point of view of a particular supplier, such as WANA countries. By estimating a sales price at which an supplier would break-even, the methodology utilizes historical volume and price data to estimate how much additional product this market would absorb during the months WANA countries could potentially supply before the price would be forced below that break-even price. The following section includes additional conceptual and methodological detail on the Profitable demand methodology is as follows.

**Profitable Demand Concept and Estimation Methodology**

Knowing when the market window of opportunity occurs in a given market is much simpler than knowing the depth or magnitude of the window. To estimate the depth of the market at the break-even price requires additional logic and analytical effort. In order to understand the results of this additional analysis, it is necessary to understand some of the underlying methodology and evidence of its soundness.

***Supply & Break-even Price Intercept Points:*** The first step in estimating *Profitable Demand*, which is to identify the points during the year when the market price is equal to the Break-even price. The Break-even price is the total cost of production, packaging, transport, tariffs and handling to place one kilo of the product in the international market.

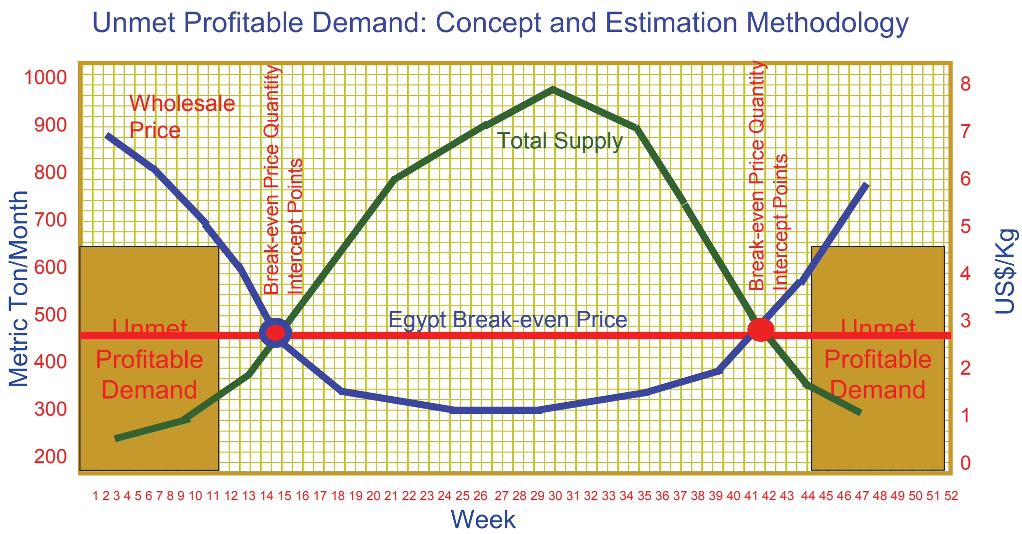



Figure 7.

**B. Potential Profitability and Value Added**

**4. Profit and VA Margins per Kg. or MT**

The first prioritization and screening criterion for potential profitability and value added is met with an indicator which estimates profit and VA margins per Kg or MT which could be obtained in a specific product/market at historical prices paid for imported products. Although frequently used, and occasionally as the principle prioritizing indicator, profit margin estimates are of limited export strategy value, and unless balanced by volume-linked profitability concepts, can miss-prioritize products and markets by focusing on opportunities where prices may fall apart under volume supply pressure.

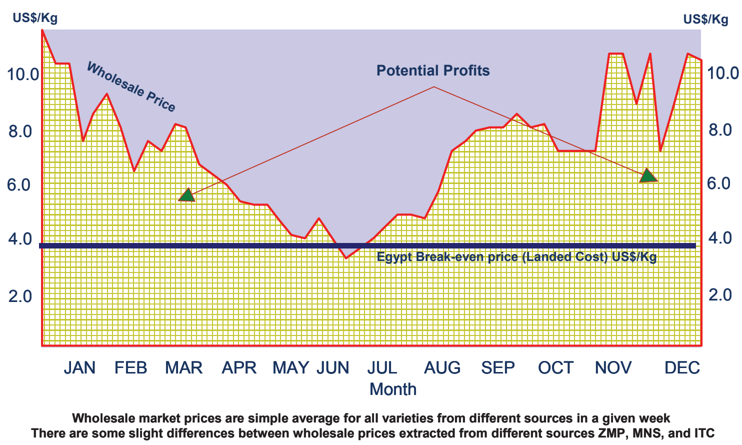



Figure 8. Strawberry average wholesale market price in Germany and potential profit

### 5. Total Profit & VA for Profitable Demand Volumes

A safer approach to prioritizing using profitability criteria is to combine unit margin estimates with total profitability and value added estimates at a predetermined point along the price/volume continuum, which is quantified in the Profitable Demand methodology. This will shift the priority focus to product/market opportunities, which present the best AND the most robust profitability opportunities.

## C. Estimated Competitive/Comparative Position

Three factors appear to be the major elements in competition between locations supplying perishable fruit and vegetables seasonal position, transport position and wage rate position. These major factors, along with other input costs and yields, combine to contribute to landed cost differences. While packaging costs and yield levels are both very important components of overall landed cost differences, these factors can and do change in the short run and do not usually represent longer run or underlying factors in competitive position. The methodology accounts for all of these factors as short run cost retailers in the last indicator, landed cost, but balances this estimate with separate consideration of differently measured longer run indicators for season, transport and wage rate positions.

### 6. Seasonal Position.

The seasonal position indicator estimates the proportion of the non- domestic supply window, which can be supplied by WANA countries. Thus if a particular country can produce a specific product to supply its demand during four months of the year and the non-domestic supply window is eight months, then WANA countries can supply that product to four of the gap months. The seasonal position prioritization and screening indicator is both an absolute and a comparative or competitive indicator. This indicator can be used as an absolute prioritization indicator; it can also be used as a competitive or comparative position indicator when placed alongside a similar estimate made for major competitive suppliers.

### 7. Transport Cost and Agility Position

Transport cost and agility indicators present a basic underlying transport position, taking into account distance and refrigerated sea traffic pattern factors. These indicators are not directly limited to average current transport pricing structures and routings, dependent as they are on volume flows, and scheduled vs. charter transport system differences. The shorter run realities of current pricing schemes is taken account of in the composite landed cost indicator 9 while this indicator 7 estimates transport costs and transit times which are expected to emerge with the volume flows implied by the Profitable Demand indicator. Thus this indicator should be a more accurate view of WANA countries's underlying geographic transport position, rather than just the current low-volume transport cost which current carriers would charge to the new-market destination. Thus indicator 7 is a longer run comparative and competitive transport position indicator while indicator 9 covers the short run transport cost reality relevant to evaluating a start-up competitive position.

Of particular competitive significance from the transport perspective are product/market situations in which the perish-ability of the product may position WANA countries to ship by sea because of its proximity to a given market where a competitor is forced to ship by air at a much higher cost. The competitive significance of these inter-modal differences will be both captured in the quantitative indicators and emphasized in the narrative analysis.

### 8. Wage Rate Position

For most perishable export crops, labor is the third largest cost, behind packaging and transport, which are respectively first or second depending on whether transport is by air or sea. Thus wage rates are a major competitive and comparative advantage factor. Although rising wage rates are an obvious objective of expanded exports and wage rates are expected to change in the short run, WANA countries comparative position vis-à-vis potential competitors is an important prioritizing and screening criteria.

### 9. Landed Cost per Unit

Figure (9) indicates the landed cost/unit estimates are intermediate steps in arriving at profitability indicators mentioned above. They may be further used as independent estimates for competitors. The landed cost indicator concept is the same whether the estimates are based on in-depth primary statistical sources, more general secondary source estimates, or bracketed sensitivity analysis estimates across a range of different yield and cost as assumptions.

### D. Export Potential

This indicator is very important at least in the short run. Production season and geographical position as well as the country exports to the potential export markets are the main quantitative indicators for these criteria.

### 10. Production season and geographical position

The capacity to compete in the target export markets effectively is another important indicator. The indicator could be traced by looking at the exports to this market during the last 5 – 10 years. If the exporters were able to hit the market even with small quantities successfully, this will give an indicator that with some modifications the exporters could increase the exports to this market.

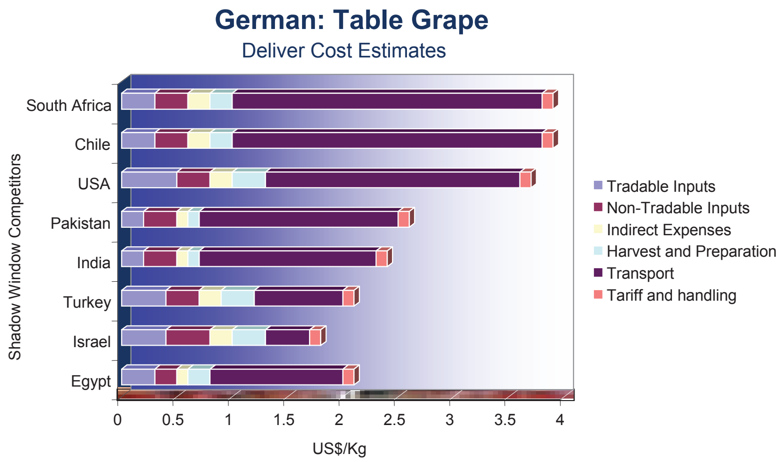



Figure 9

**Fresh Produce Export Strategy to the EU Market**

EU fresh produce market is very large and growing market. Germany, U.K. France and Italy are the major importers in the EU market. Annex includes detailed analysis for the most promising fresh produce items in the EU market. Those products have been selected based on the above outlined criteria.

## *Quality*

Quality of the product is an important factor in competitiveness and shows variations per product and channel. For example, the ideal shelf ripeness is a quality parameter where different requirements apply per sales channel. While some channels (e.g. supermarkets) prefer fairly unripe products that can be stored longer, other channels such as those supplying ethnic markets and food services prefer riper products. In general, European retail outlets (supermarkets, specialized shops, weekly markets) sell first-quality products. However, there are retail outlets that have less strict quality demands and accept products that are qualified lower than first quality The processing industry also accepts product with minor imperfections, for products such as jams, fruit juices and fruit pulps.

Many retailers in the EU nowadays require a certification from producers and exporters that assures a certain standard of quality such as EurepGAP for fresh produce and safety standards such as HACCP and BRC (in the UK) for processed food products such as pre-cut fruit and vegetables. They are becoming increasingly important for exporters to gain access to the EU retail market. Nevertheless, there are still many opportunities for non-certified products in the channels for street markets, food services and food processing industry.

### *Competitor analysis*

Competing businesses and their pricing policy in particular have a direct effect on the success of your business venture. It is therefore important to learn more about your competitive environment, i.e.: identify who your main competitors are and how they behave in the market. There are very many suppliers for fresh fruit and vegetables to the EU market. Nevertheless, the market is open to new entrants.

Producers of horticultural products in developing countries benefit from their geographic location, which offers them good climatic conditions or the possibility to supply off-season or counter-season products. These are often the most important factors that positively distinguish your company from competitors in other countries, particularly from competitors in Europe. Other positive factors are for example lower costs of labor and land.

There are also factors that weaken a competitive position. With the increase of oil prices, the cost of transport has risen significantly over the last years, especially for airfreight. European and Mediterranean producers and exporters have the advantage of being close to the market and have the possibility to transport their produce by road. In some countries, the distance from production location to the air terminal or seaport can be long, which has an effect on produce quality and delivery time. If national borders have to be crossed, the delivery time and cost can increase substantially. Another important difference is the fact that (new) cultivation technology and inputs are readily available to European producers and that these receive support from many organizations, e.g. input-supplying companies. Producers in developing countries may not have this infrastructure or easy access to this technology.

There are also factors in the export market that influence the competitive position of your business. Thanks to the development of new storage techniques and varieties that can be stored longer while retaining quality. European growers are able to expand their supply period and therefore are stronger competitors for exporters of off-season products from the southern hemisphere.

Some critical factors for building a favorable competitive position:

- Identifying market demands and increasing the range of products (diversification, new products and line extensions).
- Specialization in a limited number of high quality products.
- Cost and price calculation based on a business plan.
- Cost reduction.
- Putting emphasis on the quality of the product and exercising strong control on the tracking and tracing of products.
- Introducing the use of new technologies.
- Promoting involvement and loyalty of staff, as well as integration into the life of the local community.
- Co-operating with buyers, in order to obtain necessary pre-financing, technologies or packaging.
- Reducing the number of actors in the supply chain and retaining more added value.

Having assessed the prospective markets and market segments, it is important to understand the trade structure and supply chains supplying these market segments. After the assessment of the exporter's capabilities, this will enable the exporter to determine the most suitable sales channel.

Importers and agents are often specialized in supplying to a specific sales outlet. Many large retail chains, for example, have their own buying organization or import facility, which is responsible for the complete assortment of fruit and vegetables. Other importers and agents may focus on all sales channels other than the large retail chains. These include the specialty shops (greengrocers), where high-quality and less-common exotics may be in higher demand. Fruit combines and vegetable clusters typically have their own marketing organizations, but these are generally not accessible for independent exporters.

Only few exporters in developing countries sell directly to multiple retailers. The main reason is that exporters do not have the necessary infrastructure (sales offices, storage capacity and logistics) to satisfy the volume and delivery frequency demanded by the retailers. Those producers/exporters that currently sell to multiple retailers are often large (foreign-owned) farms or plantations that have good access to (skilled) labor, transport facilities and capital.

Long-term contracts or co-operation agreements between producers or exporters in developing countries and importers in the EU countries are becoming more important. All parties in the chain have an interest to plan in advance the amount and quality of the produce that is required, and from whom it is obtained. Retailers may even be willing to support and invest in the production to achieve the required quality, traceability and delivery frequency.

Each supply chain, from producer to outlet, has its own specific conditions, which should be met by the exporter. Food safety and tracking & tracing have become major issues in the supply chain to the multiple retailers in the EU. Many of the multiple retailers nowadays require a certification that ensures the safety and quality of the produce (for instance EurepGAP and BRC). Without the proper certificate, supply is not possible and other outlet channels need to be sought.

Important questions to be answered are:

- Which potential sales channels exist for your products in the target market?
- What are the most important requirements (quality standards, packaging etc.) of the identified sales channels?
- Which sales support material is necessary for this sales channel (e.g. offers, price lists, quality certificates, campaign folders, sales statistics, or company brochures)?
- Which ways of communication are used (phone, e-mail, or internet)?

## *Logistics*

Fruit and vegetables are perishable and often delicate products. They should be transported with care under the best-possible conditions. On the other hand, transport cost can become quite high and the exporter should decide on which transport mode is the best (lowest cost for the required quality assurance). Fruits and vegetables exported from developing countries to the EU are transported by ocean or air cargo.

**Ocean cargo and air shipping**

The cost of transport by sea is usually lower than airfreight but the transport time is longer. For highly perishable products, this could be a problem. But conditions of sea transportation have improved considerably over the last few years. The range of vessels has diversified and more temperature-controlled containers (reefers) are now available.

The market share of refrigerated containers is increasing due to technical improvement in these services and the decreasing prices. Another advantage of container shipment is that quality can be guarded more easily by climate control techniques and protection from infections from other products that are in the same vessel.

Highly perishable produce is commonly air-freighted because of the short transit time. Some high value products in low volumes are transported by air as well. The cost of moving products by air is higher than the cost of ocean transportation. Examples of products shipped by air are green beans from Kenya and papayas from Brazil. The products are loaded onto combined passenger-cargo flights (scheduled flights) or cargo planes on regular routes. Cargo planes can be operated by traditional airline companies or by specialized charter companies. Exporters that use scheduled flights are dependent on the freight space available to them per stopover.

## *Freight forwarders*

Freight forwarders arrange transportation services on your behalf. They are familiar with import and export regulations and can simplify the shipping process for you. It is important to use a forwarder that is experienced in handling fresh fruit and vegetables or other perishables, and has experienced in the destination country. Freight forwarders can also assist you in handling all the documents. Freight forwarders are cost effective to use, because they can negotiate the best rates with shipping and airlines. They usually operate on a fee basis. Freight forwarders and carriers are the best sources for obtaining freight rates. There are also companies that specialize in publishing (notably air) cargo tariffs. These publishing companies charge a fee for their services.

## *Packaging*

To ensure that the produce is protected properly during transport from the producer to the consumer, special packaging is necessary. Packaging should protect the products against mechanical damage and create a required microclimate to secure the quality. The packaging should also fit in the way that the products are handled. The transportation volume must be as efficient as possible and a high level of uniformity of packaging is desirable. EU growers and traders generally use boxes with measurements that allow for easy palletizing. Packaging design should consider the following:

- Proper storage and transport;
- Standard packaging sizes;
- Recyclable materials or two-way systems;
- Attractive and sales-promoting design.

The following external sizes are generally accepted in most international transport:

- Boxes: 600 x 400 mm (ISO module), or 300 x 400 mm (half ISO module)
- Pallets: 1,000 x 1,200 mm (industrial pallets), or 800 x 1,200 mm (Euro-pallets) The exporter should always discuss the preferred type of packaging with the customer.
- International Federation of Freight Forwarders Association (FIATA): http://www.fiata.com
- Directory of Freight Forwarding Services: http://www.forwarders.com
- International Air Transport Association (IATA): http://www.iata.org

## *Value chain*

The value chain covers all activities involved in transforming raw materials to end products. The value-chain approach means that each stage or activity in the chain adds value to the product, required by chain actors further along the chain or the final consumers. To gain access to a market and be competitive, a company needs to meet the buyer's requirements and market conditions; the value chain approach is a useful tool to achieve this. A value chain should be flexible and allow for a quick response to changing buyers' requirements.

The value-chain approach allows for improving the efficiencies in the supply chain and enhancing, thereby improving the profitability of companies participating in the chain. It is important to understand where you fit in the supply chain and to ensure that the value you add continues to be important for your direct customers, as well as your customers' customers and in particular the final consumer.

Activities in value chain analysis at company level include:

1. Identify all the steps required to get from raw materials to end users.
2. Make this list as detailed as possible, since one of the objectives of value-chain analysis is to understand where, when and how to simplify or adjust the chain.
3. Determine the value added by each step to the final product from the point of view of the end user.
4. Once the chain is clear, you can explore ways to improve it, with the aims of increasing your own turnover and profitability as well as the benefits to the end user, by for example:
    - Combining steps to increase flexibility;

- Eliminating steps that are just adding costs and no value;
- Determining better communication flows in both directions to assist rapid adjustment to changes in market requirements;
- Determining and expanding your own "value niche" along this chain.

## Internal analysis – fresh produce export company audit

The internal analysis or company audit involves a review of the company's strengths and weaknesses in terms of all company resources. These resources include export marketing capabilities, finance, personnel, internal organization, management, infrastructure, etc. It is a helpful instrument to assess your company's ability to take advantage of the opportunities. Furthermore, with a thorough understanding of your company's unique capabilities, you will be able to identify opportunities and develop an investment strategy.

### *Product standards, USP and production capacity*

### *Product range*

By reviewing the company's product range and product characteristics in light of the identified market opportunities, the exporter can adjust the product offer. A product range can consist of several product groups (range width), each with several different products (range depth). A buyer can only select a suitable business partner when he receives correct information about the products that the exporter has to offer. Keep in mind that varieties are sometimes known under different trade names overseas.

The next step is to review product characteristics of the products and varieties on offer. Example of product characteristics

| **Example of product characteristics** | | | | | |
|---|---|---|---|---|---|
| **Product group** | **Product Variety** | **Size** | **Supply period** | **Packaging** | **Availability** |
| Melons | honey Dew Gold Rind | 2 kg | November to February | 600*400 mm two-way plastic box | 5 tonnes per season |

### *USP*

Developing a Unique Selling Proposition (USP) is very helpful in understanding and promoting your company and products. The USP is what differentiates your product or service from your competitors. There are two major benefits in developing the USP. Firstly, it clearly differentiates your business in the eyes of your current and potential customers or clients. Secondly, it focuses your staff on delivering the promise of the USP, thus helping to improve your internal performance.

What a USP could look like: One sentence; clearly written, unambiguous and preferably simple; Believable; composed of one or two benefits that are unique to your company or product.

USPs for the fresh fruit and vegetable sector could be based on the following aspects:

- Good price-quality ratio
- Product specifications exceeding the requirements of trade partners
- Consistent and high quality of products guaranteed by the exporter
- Providing good service (replying within 24 hours to any question or request, open communication, on-time delivery, honoring agreements to the letter, even when they have financial implications)

It is important to integrate the USP in the overall marketing strategy and in all elements of the marketing mix.

### *E-commerce*

E-commerce is a relatively new method of marketing, which allows physical processes (telephone, fax and paper work) to be replaced by electronic processes. In most cases it is an open system, which can be used by companies anywhere if an appropriate infrastructure is present. Business-to-business (B2B) companies have emerged that operate e-commerce sites on the internet. The number of these types of websites has grown over the last years, but they are not of major importance in the international fruit and vegetables trade at this moment. Some of these websites have disappeared as quickly as they emerged. The growth of these B2B sites can be explained by three main advantages: they reduce transaction costs, improve efficiency, and expand the trading horizon. They have low barriers to entry, unlike earlier forms of electronic data interchange. In the coming years, they may therefore also have a significant impact on exporters in developing countries. Some of these sites mediate in selling any type of fresh food, seafood, meat, dairy, fruit and vegetables.

### *Financing*

Export marketing requires financial resources. If they are limited and cannot be acquired easily, marketing plans will have to be modest. It would be wise to invest only in one or two new markets when finances and time are limited. Local banking systems in developing countries are sometimes not capable of handling exports. It is therefore recommended to use an international bank that is also located in the importing country. This will also simplify and speed up the payments from your business partners. Each country has a list of local banks with partner banks in other countries or financial institutes with which they have a special relationship.

### *Capabilities*

Apart from the subjects mentioned above, the following capabilities should be assessed as part of the internal analysis.

### *Commitment to export*

It is important for a company to consider whether it has people who are able to develop an international business and sell the produce (close a deal). The company should be able to generate the physical and administrative infrastructure to deal with increased activities from exporting - not only in dealing with orders but also with processing customs and shipping documentation. If this type of infrastructure is limited, the company can outsource it to a specialized organization against a cost.

### *Export experiences*

It is important to learn from experiences. If the company has tried and failed to enter a new export market previously, it should be analyzed to determine what went wrong.

## Decision making

### *SWOT and situation analysis*

A SWOT analysis is a tool for analyzing the internal environment (Strengths and Weaknesses of the organization) and the external environment (Opportunities and Threats). It is a tool to identify new market opportunities and assess the competitive position of the company in the selected market. SWOT analysis helps an exporter to focus his activities on areas where he is competitively strong and where the greatest opportunities lie. A SWOT analysis is just one of many techniques for a company to gain insight in its competitive position.

## *Questions that need answering:*

Strengths:

- What are your capabilities?
- What capabilities do you consider as your strengths?
- What relevant resources do you have to support those capabilities?
- What do other people see as your strengths?

*Weaknesses:*

- What capabilities do you consider as your weaknesses?
- Are you able to improve the performance of these capabilities?
- What capabilities should you avoid in search for competitive advantage?

*Opportunities:*

- What are the interesting trends and developments in the market?
- Which trends or developments constitute an opportunity for your company?
- What are the benefits stemming from the opportunity?
- Are you able to fulfill the requirements (do you have the critical capabilities)?

*Threats:*

- Are the market demands for your products or services changing?
- Is changing technology threatening your position?
- What is the seriousness and probability that these threats hurt your business? • What are the competitive advantages of your competitors?
- Does the financial rate of return exceed the required threshold for investments?

## *Export marketing tools*

Which marketing tools can you use to build your export business successfully and how to use them?

## *Building up a relation with a suitable trading partner*

One of the major obstacles for exporters can be to find, attract and secure a serious importer or trade partner. There are many ways for locating trade partners and an exporter should choose one that is most appropriate for the targeted sales channel.

**How to find a potential trading partner?**
The best ways for exporters in developing countries to approach potential trading partners in the European fresh fruit and vegetable market are:

- Direct mail: You can write a letter, e-mail or fax directly to a European company. Many companies will not respond at all or respond that they are not interested. However, only a few positive replies are needed. It is important to follow up immediately on the companies that have responded positively.
- Personal visits: Once you have received a number of "interested" replies, plan a trip to those companies or organizations. If it is possible stop in other potential markets while traveling to assess the situation and try to make contacts. Many times a personal visit will pay off in terms of the benefits gained.
- Invite EU importers or potential business partners to visit your company.
- Build a network in order to extend your contacts.
- Visit international trade fairs.

**How to identify the most suitable trade partner?**

- You can evaluate the information on a potential trade partner based on the following criteria:
- Is the information complete (address, telephone and fax numbers, e-mail address, name of contact person)?
- What kind of trade relation is the potential trade partner interested in (arms-length, co-operative agreement, contract basis)? Does this correspond to your preferred type of relationship?
- What is the position of the potential trade partner in the market? • What is the financial status and credibility of the company?

## *Price setting*

If prices are defined by the market, target costing is a useful tool. In this manner, not costs are the starting point but the target sales price. This way an exporter can try to ensure that the costs of the products do not exceed the target costs. Determining the price of your product is worth considerable effort, since it directly affects your profit margin. An exporter can choose to find and exploit a section of the market that is relatively insensitive to price changes. This price-skimming policy, however, is difficult to use in the fruit and vegetables market since it very competitive and dynamic.

# Annexes

## Export Market Potential for Selected Fresh Produce Items of interest to the regional suppliers

### *Strawberry*

Strawberry is one of the most potential for profitable horticultural exports to the EU and GCC markets. Off-season prices are quite high, and with appropriate technology growers could supply these markets during the highest price periods. Strawberry markets are large and growing in most West European countries and GCC markets as well. The largest two markets are Germany and France.

Germany is by far the largest importing country with about 123 thousand tones imported each year. The UK is a smaller but profitable market. While the Netherlands looks like a large importer, that is partly due to the importance of Rotterdam as major port for incoming produce destined for the rest of Western Europe

Germany and France are the two largest potential export markets. The share of Germany imports amounted to 50% of total EU imports of strawberry 2006; France imports amounted to 25%. The two countries absorb more than 75% of total EU imports. It appears that the two countries can absorb roughly 4,000 metric tones per week at prices profitable to the exporter.

The major Non-EU suppliers are Poland, United States, Israel, and Morocco. Spain is the major player in the late summer market. Non-EU Imports fluctuate partly in response to the size of local European harvests, but this effect is limited to small part of season when local production is possible.

***Germany***

The German market presents the largest amount of potential Un-Met demand of the four markets. The German Profitable Demand line is drawn at roughly 26,000 metric tones per month. During the five months when the market window is open to WANA countries , this would imply a total profitable demand of roughly 130,000 metric tones.

During the three months before the window closes in March, competitors are already meeting some of the profitable demand. This leaves the overall depth of the window at over 44,000 tones per year.

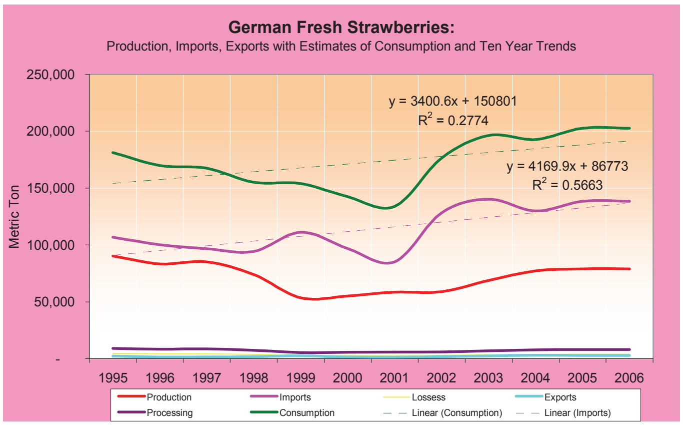



Figure A-1: Germany fresh strawberries: Production, imports, exports. Estimates of consumption and ten year trend

The overall shape of the weekly supply line during 1998-2006 years suggests a fairly stable supply situation. May is always the high supply period. This is when Germany and its major suppliers are at peak production.
Spain and Italy supply most of the strawberry to the German market. Spanish supplies enter the market in February and reach their peak in April and May.

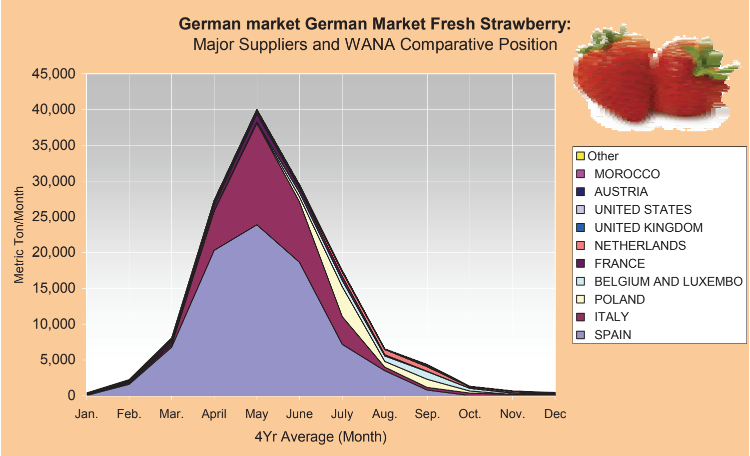
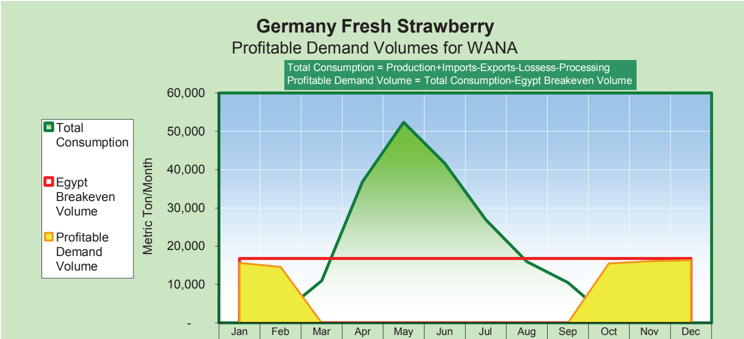



**Figure A-2: Germany fresh strawberry: major suppliers and WANA countries comparative position**

They can supply up to 4,000 MT/Week during the peak months. German domestic production enters into the market much later and usually peaks in May.

Italy, Belgium and Netherlands also supply fairly large portions of the German market. They compete directly with Spain during the on-season February-June. Italy and Belgium have supplied over 500 MT/Week during May. Most of the competition in the German market is concentrated around on-season, leaving a large market window open for new competitors.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Consumption | 1,170 | 2,213 | 11,001 | 36,846 | 52,309 | 41,693 | 26,924 | 15,954 | 10,469 | 1,302 | 658 | 410.00 |
| Egypt Breakeven Volume | 16745.6 | 16745.6 | 16745.6 | 16745.6 | 16745.6 | 16745.6 | 16745.6 | 16745.6 | 16745.6 | 16745.6 | 16745.6 | 16745.6 |
| Profitable Demand Volume | 15575.6 | 14532.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15443.6 | 16087.6 | 16335.6 |
| Monthly CIF US$/Kg | 3.14 | 2.89 | 1.87 | 1.73 | 1.42 | 1.24 | 1.07 | 1.37 | 1.58 | 1.93 | 4.31 | 4.15 |
| Egypt CIF US$/Kg | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 |

Month of 2002-2006 (5Yr Average)

Figure A-3: Germany Fresh Strawberry Profitable Demand and Volumes for WANA countries

German domestic supplies do not affect the German market like the domestic supplies do in the French market. The small size of the domestic supply allows the wholesale price to remain above the break-even price for the whole year. The lack of domestic supplies also opens the market to competitor countries, but there is still a good off-season market potential in Germany.

Poland, USA and Morocco are round out the top suppliers in the German market. These countries do not have a significant portion of the market. There are several countries that provide a significant amount of strawberry to the U.K. market during the off-season

***The United Kingdom***

In the U.K. market, the profitable demand level is estimated at 5,500 tones per month. The window is open for five months with a total depth of approximately 27,500 tones. The UK market is fairly stable market.

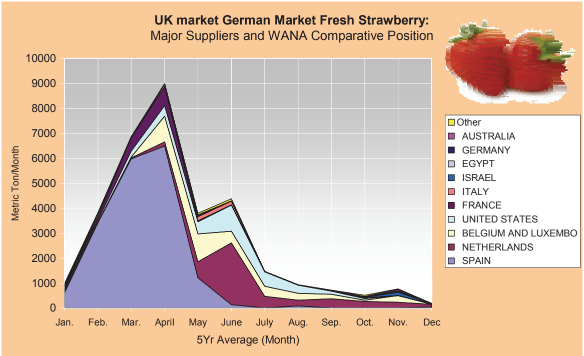
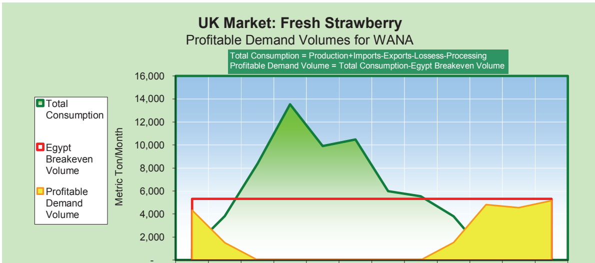



Figure A-4: UK Fresh Strawberry Major Suppliers

The beginning of the on-season supply usually starts in the 12th week of each year and rises to a high point in May. The producer should try to fill the market window during the period of November – March. Concentrating more on the time frame starting at the end of the year,

Morocco and Israel are the significant off-season suppliers with supplies beginning in July and continuing until November. Colombia has captured a small market window by supplying the market in July and August while few other countries are filling this period.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Consumption | 986 | 3,808 | 8,375 | 13,542 | 9,916 | 10,488 | 5,975 | 5,543 | 3,790 | 509 | 771 | 165.00 |
| Egypt Breakeven Volume | 5322.4 | 5322.4 | 5322.4 | 5322.4 | 5322.4 | 5322.4 | 5322.4 | 5322.4 | 5322.4 | 5322.4 | 5322.4 | 5322.4 |
| Profitable Demand Volume | 4336.4 | 1514.4 | 0 | 0 | 0 | 0 | 0 | 0 | 1532.52 | 4813.4 | 4551.4 | 5157.4 |
| Monthly CIF US$/Kg | 2.69 | 2.00 | 2.08 | 1.93 | 2.19 | 2.12 | 1.76 | 1.58 | 2.22 | 2.62 | 2.91 | 3.38 |
| Egypt CIF US$/Kg | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 |

Figure A-5: UK Fresh Strawberry Profitable Demand

## France

France imports are strengthening over time. From 1990, France imports increased at an average annual rate of more than 10 percent. The major non-EU suppliers are Morocco and Poland. Spain and Belgium are the main EU competitors.

Profitable demand in the French market is estimated at approximately 16,000 metric tones per month, making it the second largest market behind Germany. The reason for the large size of the French market is mainly to the size of the French domestic production.

From March until June the French market window is closed to WANA countries . Quantities supplied often exceed 15,000 metric tones per month during this period. The sizeable domestic market cases prices to fall during the summer months, especially during the months of April, May and June.

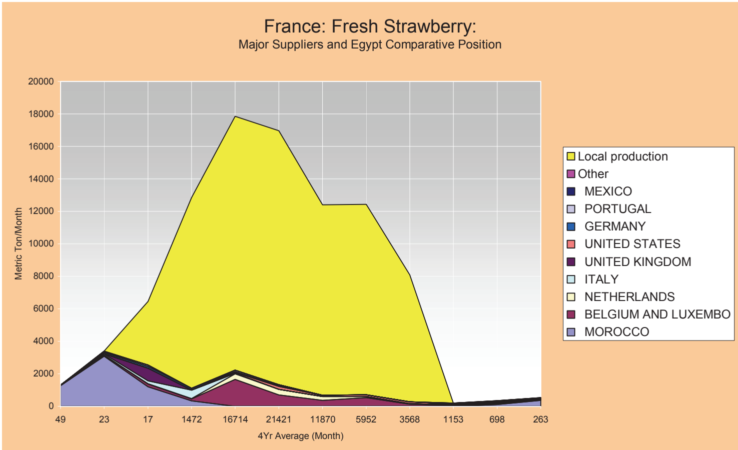
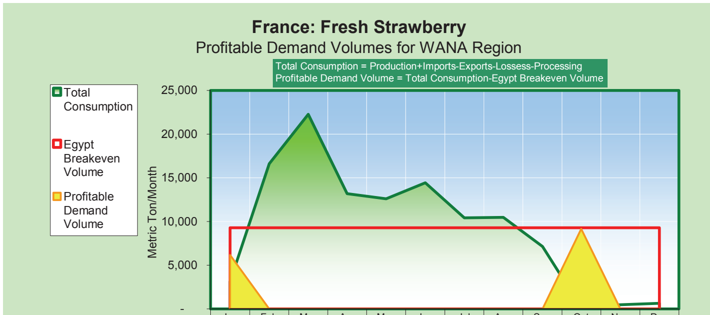



**Figure A-6: France fresh strawberries: major suppliers and WANA countries 's comparative**

Total unmet profitable demand in France totals approximately 80,000 metric tones. This represents a great potential market if strawberries can be supplied during the off-season period (November to February). Spain is dominant in the domestic market during the on-season. Only one other country (Morocco) is clearly visible.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Consumption | 3,134 | 16,601 | 22,274 | 13,199 | 12,602 | 14,441 | 10,429 | 10,474 | 7,154 | 156 | 500 | 662.00 |
| Egypt Breakeven Volume | 9302.3 | 9302.3 | 9302.3 | 9302.3 | 9302.3 | 9302.3 | 9302.3 | 9302.3 | 9302.3 | 9302.3 | 9302.3 | 9302.3 |
| Profitable Demand Volume | 6168.27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9146.27 | 0 | 0 |
| Monthly CIF US$/Kg | 2.26 | 1.65 | 1.15 | 0.91 | 1.57 | 2.33 | 2.55 | 2.74 | 1.45 | 3.38 | 1.49 | 1.24 |
| Egypt CIF US$/Kg | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 | 1.89 |

Month of 2002-2006 (5Yr Average)

**Figure A-7: France Fresh Strawberry Profitable Demand**

The domestic market begins in late February and continues until July. Domestic supply peaks during May and June.

Even though domestic supply dominates the market, there is a large off-season market that could be supplied by the producer. Spain is largest supplier of strawberries to France. It competes during the first part of the French domestic production, choosing to supply in November and December.

Other countries such as Poland, Mexico, and Colombia supply portions of strawberry to the French market, but are dwarfed by the size of the domestic production. The Netherlands market is much smaller in size than other three markets.

The profitable demand level is estimated at only 3,000 tones per month. The window is open for five months with a total depth of approximately 3,000 tones. The beginning of the on-season supply usually starts in the 12th week of each year and rises to a high point in April-June. There is more competition from off-season competitors throughout the entire year.

The producer should try to fill the market window during the period of November and December, concentrating more on the time frame starting at the end of the year. This is when competition is the weakest and as we will discover later, the wholesale prices are the highest.

## *Table Grapes*

Total grape imports in Western Europe were subjected to rapid increase over the last five years. The major importing countries in Europe and North America have become more conscious about nutrition and physical fitness. This trend has been gaining strength and is now beginning to exhibit itself strongly in the marketplace in the form of a shift in consumption in favor of fresh fruits and vegetables. There is a similar consumption trend, which has favorably affected the market for fresh produce, which is related to the link between cholesterol and heart disease. Recent research has confirmed the link, and a significant proportion of the consuming population is now shifting diet in the direction of fresh fruits and vegetables.

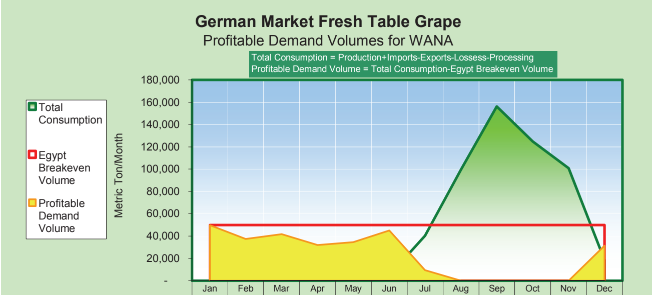
Table grape markets are large and growing in West European countries. The largest four markets are Germany, France, UK, and Netherlands. Germany is the largest consuming country of these four with imports amounting to 363,000 thousand tones in 2006, and is by far the largest importing country because domestic supply is almost nonexistent. France is the second largest importer with 135,000 tones followed by UK with 135 tones, and finally Netherlands with 117,000 in 2006. Total imports of table grape for the four markets amounted for 783,000 Tonnes (91% of total EU grape imports in 2006). Data indicate that grape import trends in Europe are strengthening over time. This dramatic recent expansion in grape imports into Europe is very clear.

### *Germany*

The surge in grape imports by Germany is striking and has experienced significant growth during the period from 2002-2006. Germany experienced an annual increase in grape imports during that period amounting to 15,500 tones. This clearly indicates that the German market has limited production capacities and a strong growing demand with resultant positive import trends. The market is still unsaturated and open for serious off-season suppliers.

Total grape supply in the German market is concentrated in the period from July until November. German domestic supplies do not affect the German market. The absence of a domestic supply allows the wholesale price to remain above the break-even price for almost the whole year. The German profitable demand is drawn at roughly 50,000 tones per month. During the 7 – 8 months when the market window is open to WANA countries , this would imply a total profitable demand of roughly 400,000 metric tones. During the months before the window closes in August and months after it reopens in November competitors are already meeting 25% of the profitable demand. This leaves the overall depth of the window at over 300,000 tones per year. Improved quality with the same growing conditions and technologies permits WANA countries to increase supplies to the German market by approximately 177,000 tones during May and June. Italy, Greece and Spain supply most of the grapes to the German market. Italian supplies enter first into the market in June with small supplies and then as the Italian season comes into full swing by September supply rises to over 60,000 tones per month. During the Italian peak in October, Italian supplies can reach 70,000 tones per month. Italian supplies trail off abruptly in late October, but continue into November. Greek supplies appear in the German market during the same market period as Italy. Greek supplies begin in July and peak in October. Spain is the third largest supplier in the German market. Spanish supplies avoid much of the saturated market period of September and October. Spain supplies enter in the market in July and August, decrease rapidly and then enter the market again in November. Chile and South Africa are the largest suppliers in the off-season. Chile begins to supply the market during the month of January and continues to supply up to 1000 tones per month until April. WANA countries should try to supply the French market during the same period. South Africa supplies the German market during the same period as Chile.

The lack of domestic supplies also opens the market to competitor countries, but there is still a good off-season market potential in Germany. Prices in the German market, as in other EU markets, are very attractive to exporters. Wholesale prices never drop below break-even prices during market windows.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Consumption | 250 | 12,602 | 8,149 | 17,896 | 15,480 | 4,878 | 40,328 | 99,691 | 156,16 | 124,72 | 100,84 | 18,525. |
| Egypt Breakeven Volume | 49961.7 | 49961.7 | 49961.7 | 49961.7 | 49961.7 | 49961.7 | 49961.7 | 49961.7 | 49961.7 | 49961.7 | 49961.7 | 49961.7 |
| Profitable Demand Volume | 49711.7 | 37359.7 | 41812.7 | 32065.7 | 34481.7 | 45083.7 | 9634.12 | 0 | 0 | 0 | 0 | 31436.7 |
| Monthly CIF US$/Kg | 1.26 | 0.98 | 1.49 | 1.52 | 1.38 | 1.45 | 1.33 | 0.83 | 0.80 | 0.74 | 0.81 | 0.96 |
| Egypt CIF US$/Kg | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 |

Month of 2002-2006 (5Yr Average)

**Figure A-8: Germany Fresh Table Grapes – Profitable Demand Volumes for WANA countries**

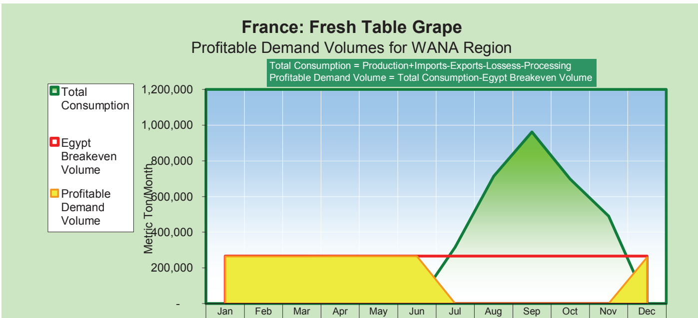
### *France*

The French grape import trend has experienced significant growth during 2002 –2006 with an annual increase in grape imports during that period amounting to 7,500 tonnes. This clearly indicates that the French market has limited production capacities and a strong growing demand with resultant positive import trends. The market is still unsaturated and open for serious off-season suppliers.

Total grape supply in France is concentrated in the period July until November. French domestic production from Southern France can begin earlier in small volumes. The French profitable demand is drawn at roughly 29,000 tonnes per month. During the 7 – 8 months when the market window is open to WANA countries, this would imply a total profitable demand of roughly 232,000 metric tones. During the months before the window closes in August and months after it reopens in November competitors are already meeting one-eighth of the profitable demand. This leaves the overall depth of the window at over 203,000 tonnes per year.

Improved quality with the same growing conditions and technologies permit WANA countries to increase supplies to the French market by approximately 56,000 tonnes during May and June. Italy and Spain supply most of the grapes to the French market. Italian supplies enter first into the market in June with small supplies and then as the Italian season comes into full swing by September supply rises to over 30,000 tonnes per month. During the Italian peak in October, Italian supplies can reach 40,000 tonnes per month. Italian supplies trail off abruptly in late October, but continue into November. Chile and South Africa are the largest suppliers in the off-season.

Chile begins to supply the market during the month of January and continues to supply up to 1000 tonnes per month until April. WANA countries should try to supply the French market during the same period. South Africa supplies the French market during the same period as Chile.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Consumption | 2,621 | 2,715 | 2,149 | 1,957 | 1,900 | 1,957 | 315,48 | 713,21 | 962,53 | 696,54 | 489,77 | 8,192.0 |
| Egypt Breakeven Volume | 266586. | 266586. | 266586. | 266586. | 266586. | 266586. | 266586. | 266586. | 266586. | 266586. | 266586. | 266586. |
| Profitable Demand Volume | 263966 | 263872 | 264438 | 264630 | 264687 | 264630 | 0 | 0 | 0 | 0 | 0 | 258395 |
| Monthly CIF US$/Kg | 1.84 | 1.31 | 1.47 | 1.36 | 1.36 | 1.22 | 1.28 | 0.77 | 0.65 | 0.71 | 0.95 | 1.49 |
| Egypt CIF US$/Kg | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 |

Month of 2002-2006 (5Yr Average)

**Figure A-9: France Table Grape Profitable Demand**

***The United Kingdom***

The U.K. grape import trend has experienced significant growth from 1998-2006 with an annual increase in grape imports during that period amounting to 2,300 tonnes. This clearly indicates that the U.K. market has limited production capacities and a strong growing demand with resultant positive import trends. The market is still unsaturated and open for serious off-season suppliers.

The April, May and June window for grape in the UK market is very clear. The gap between off-season supplies and on-season period in the UK market opens an excellent situation for grape in the UK market.

Total grape supply in the UK market is concentrated in two periods. Italian supplies dominate the period July until November. Chile and South Africa dominate the off-season period. The UK profitable demand is drawn at roughly 32,000 tonnes per month. During the four months when the market window is open to WANA countries , this would imply a total profitable demand of roughly 128,000 metric tonnes. Competitors are already meeting roughly 100,000 tonnes of the profitable demand. This leaves the overall depth of the window at over 16,000 tonnes per year. Italy, Greece and Spain supply most of the grapes to the UK market. Italian supplies enter first into the market in July with small supplies and then as the Italian season comes into full swing by October supply rises to over 4,000 tonnes per month. During the Italian peak in October, Italian supplies can reach 6,000 tonnes per month. Italian supplies trail off abruptly in late October, but continue into November.

Greek supplies appear in the German market during the same market period as Italy. Greek supplies begin in July and peak in October. Spain is the third largest EU supplier in the UK market. Spanish supplies avoid much of the saturated market period of September and October. Spain supplies enter in the market in July and August, decrease rapidly and then enter the market again in November.

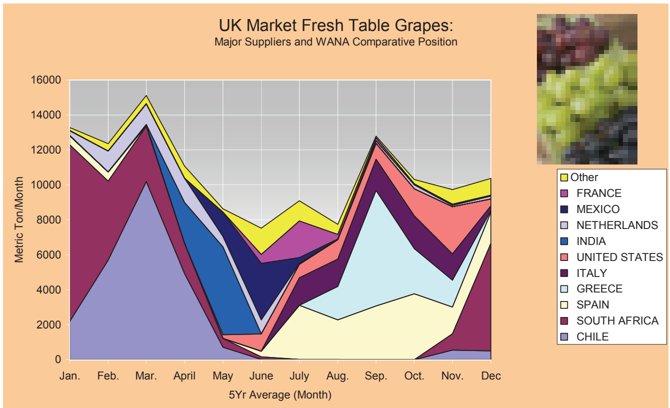
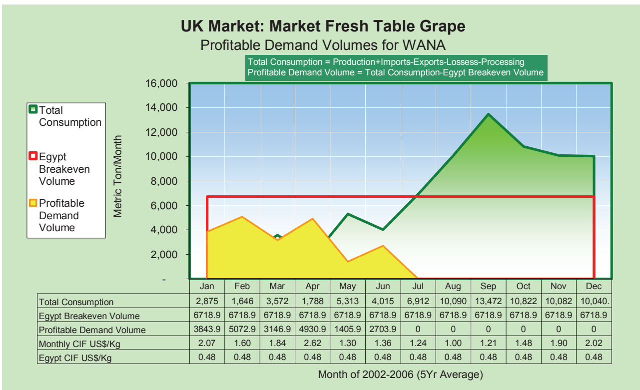



Figure A-10: UK Fresh table Grapes Major Suppliers and WANA countries Comparative Position

Chile and South Africa are significant suppliers in the typical off-season period. They often supply over 10,000 MT/Month from February to May. The lack of domestic supplies also opens the market to competitor countries, but there is still a good off-season market potential in Germany.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Consumption | 2,875 | 1,646 | 3,572 | 1,788 | 5,313 | 4,015 | 6,912 | 10,090 | 13,472 | 10,822 | 10,082 | 10,040. |
| Egypt Breakeven Volume | 6718.9 | 6718.9 | 6718.9 | 6718.9 | 6718.9 | 6718.9 | 6718.9 | 6718.9 | 6718.9 | 6718.9 | 6718.9 | 6718.9 |
| Profitable Demand Volume | 3843.9 | 5072.9 | 3146.9 | 4930.9 | 1405.9 | 2703.9 | 0 | 0 | 0 | 0 | 0 | 0 |
| Monthly CIF US$/Kg | 2.07 | 1.60 | 1.84 | 2.62 | 1.30 | 1.36 | 1.24 | 1.00 | 1.21 | 1.48 | 1.90 | 2.02 |
| Egypt CIF US$/Kg | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 | 0.48 |

Figure A-11: UK Fresh Table Grapes Profitable Demand Volumes for WANA countries

## *Green Beans*

WANA countries can deliver beans cheaper than any of these competitors. While their production costs are competitive, WANA Countries has an advantage over Kenya, Senegal and Burkina Faso because its transport costs are lower. The Canary Islands has low freight costs, but their costs of production are higher. The United States produces a lot of high quality green beans, but high production and transport costs make it uncompetitive in the EU market.

The present analysis focuses exclusively on "fine" fresh beans, since consumers, and therefore processors pay a significantly lower price for bobby beans. The prices and potential profit margins for fresh "fine" beans in European countries are high, especially during the off-season. With appropriate production and post-harvest technology, growers could supply these markets during the highest price periods.

German market prices are near or below the break-even line in the on-season from June through September. The prime market window for WANA is December – May. Based on 2006 prices, the profit potential for exporters would range from about $1.00 to $2.50 per kilo during that period.

Profits are low to negative during June-August. The best profit margin for Germany appears to be in February, March and May, when profits are often above $2.00/Kg.

The UK market, while a small market for beans, has good profit potential during the entire year. The shaded area never falls below the black breakeven price line, indicating that profits may be realized during the whole year. However, the producer should concentrate on the February – April period when profits would be about $3.00 per kilo.

During March and early April the wholesale price is about $6.00/Kg. Potential profits are about $3.00 per kilo during that period. During the rest of the year, profit potentials in the UK market range from less than $1.00 to $2.00.

The French wholesale prices are somewhat lower than in the UK market. Wholesale price drops below the break-even price in May – June and again in August. Exporters can make their best profits in March and in October. Potential profits would range from $1.00 to $2.00 per kilo.

The most attractive market window for WANA in the French market is in the month of March, with profit potential of about $2.00 per kilo. Profit potentials are also reasonably good in October – November. exporters should avoid the May – September period.

The Netherlands wholesale prices are even lower than in the French market and are very stable throughout the year. There is no highly attractive market window. Profit potentials are about $1.00 per kilo throughout the year.

The Netherlands market presents marginal opportunities for the exporter. Prices remain low but stable throughout the year. Profits range from about $.75 to $1.50 per kilo.

WANA countries lies in the most flexible possible climatic position. With appropriate production technologies and varieties, WANA countries should be able to produce for selected off-season markets and compete favorably in the front edge of the on-season as well.

### *Germany*

The German Profitable Demand line is roughly 6000 metric tonnes per month. The peak import level, in June, indicates that German consumers have already demonstrated a willingness to purchase that quantity of imported beans at a price that would be profitable for the exporter.

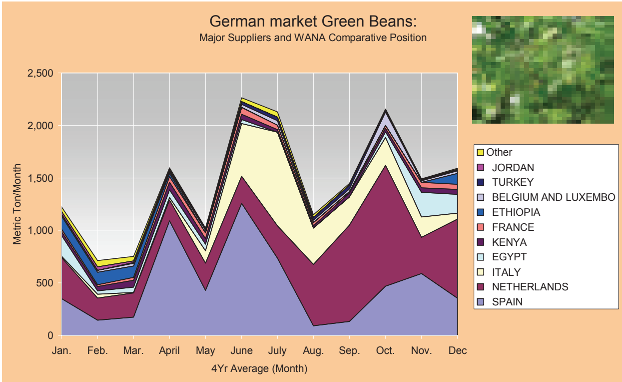
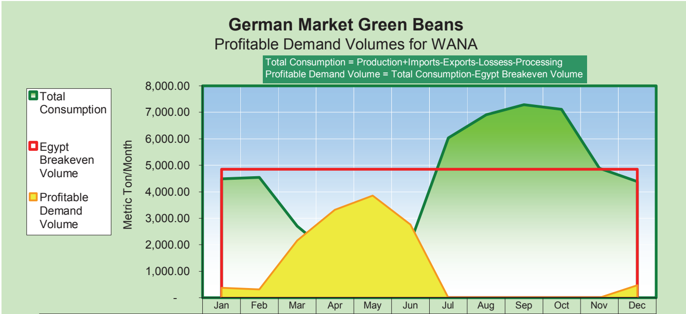



**Figure A-12 Germany Green Beans Major Suppliers and WANA countries Comparative Position**

During the nine months when the market window is open to WANA countries , this would imply a total profitable demand of roughly 54,000 metric tonnes.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Consumption | 4,485.7 | 4,542.7 | 2,700.3 | 1,533.0 | 1,000.0 | 2,089.0 | 6,029.7 | 6,906.1 | 7,289.1 | 7,116.1 | 4,888.7 | 4,388.7 |
| Egypt Breakeven Volume | 4855.6 | 4855.6 | 4855.6 | 4855.6 | 4855.6 | 4855.6 | 4855.6 | 4855.6 | 4855.6 | 4855.6 | 4855.6 | 4855.6 |
| Profitable Demand Volume | 369.786 | 312.786 | 2155.17 | 3322.55 | 3855.55 | 2766.55 | 0 | 0 | 0 | 0 | 0 | 466.786 |
| Monthly CIF US$/Kg | 2.27 | 2.11 | 1.94 | 1.49 | 2.42 | 1.77 | 2.06 | 0.89 | 0.88 | 0.85 | 1.22 | 1.08 |
| Egypt CIF US$/Kg | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 |

Month of 2002-2006 (5Yr Average)

**Figure A-13 Germany Green Beans Profitable Demand**

### *France*

Profitable demand in the French market is estimated at approximately 2,500 metric tonnes per month, making it the second largest market behind Germany.

The total unsatisfied annual demand during the nine months when the market is under supplied is 22,500 tonnes. As in all EU markets, the period from June through August is unprofitable for WANA countries . Spain and Italy are major intra-EU suppliers with significant shipments in April – July and somewhat smaller quantities in October – December. The major non-EU suppliers during that same period are Morocco and Kenya. During the off-season, from December through

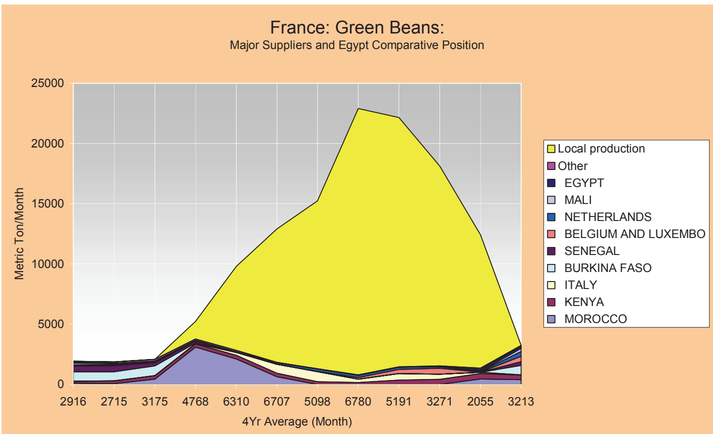
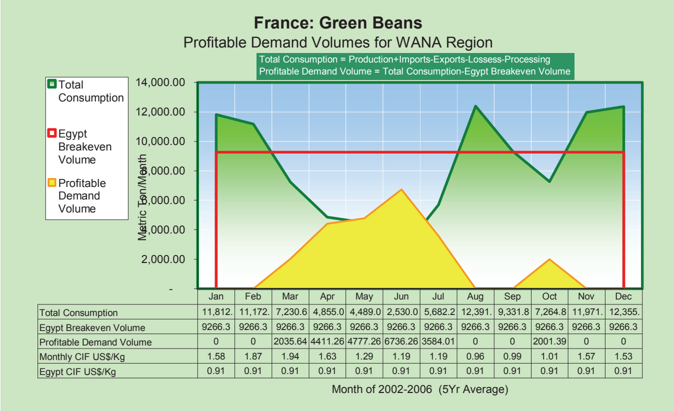



Figure A-14 France Green Beans Major Suppliers

February, Burkina Faso and Senegal are major suppliers. WANA countries ships small quantities in November – December.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Consumption | 11,812. | 11,172. | 7,230.6 | 4,855.0 | 4,489.0 | 2,530.0 | 5,682.2 | 12,391. | 9,331.8 | 7,264.8 | 11,971. | 12,355. |
| Egypt Breakeven Volume | 9266.3 | 9266.3 | 9266.3 | 9266.3 | 9266.3 | 9266.3 | 9266.3 | 9266.3 | 9266.3 | 9266.3 | 9266.3 | 9266.3 |
| Profitable Demand Volume | 0 | 0 | 2035.64 | 4411.26 | 4777.26 | 6736.26 | 3584.01 | 0 | 0 | 2001.39 | 0 | 0 |
| Monthly CIF US$/Kg | 1.58 | 1.87 | 1.94 | 1.63 | 1.29 | 1.19 | 1.19 | 0.96 | 0.99 | 1.01 | 1.57 | 1.53 |
| Egypt CIF US$/Kg | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 |

**Figure A-15 France Green Beans Profitable Demand**

***United Kingdom***

The UK market is the smallest of the four countries analyzed. Profitable demand is estimated at 800 tonnes per month. During the nine-month market window total profitable demand would be 7,200 tonnes.

Prices are higher in the UK market than other countries, so potential profits are higher. This suggests that exporters should concentrate on satisfying the 200 to 400 tonnes per month, which is not being supplied by competitors.

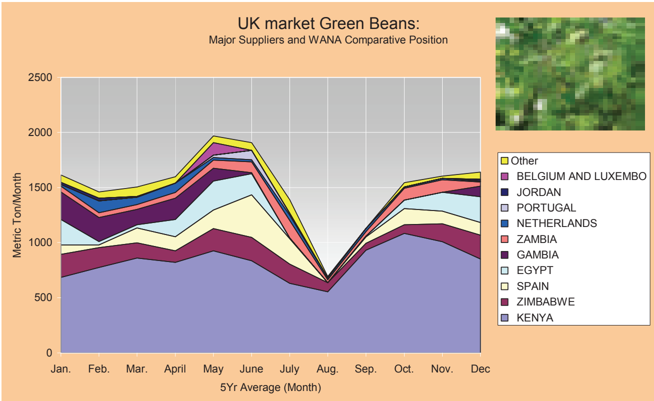
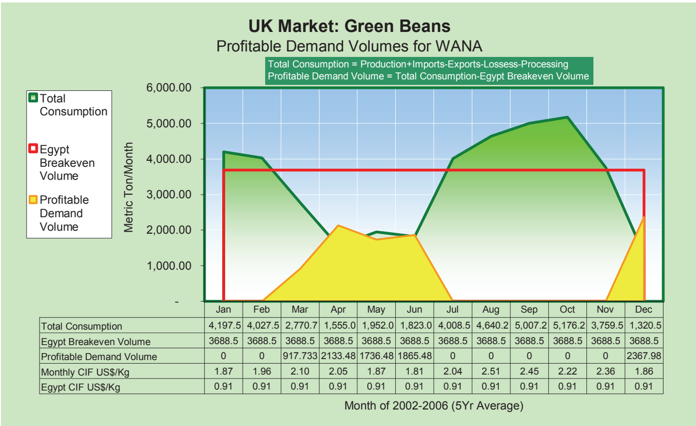



**Figure A-16 UK Green Beans Major Suppliers**




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Consumption | 4,197.5 | 4,027.5 | 2,770.7 | 1,555.0 | 1,952.0 | 1,823.0 | 4,008.5 | 4,640.2 | 5,007.2 | 5,176.2 | 3,759.5 | 1,320.5 |
| Egypt Breakeven Volume | 3688.5 | 3688.5 | 3688.5 | 3688.5 | 3688.5 | 3688.5 | 3688.5 | 3688.5 | 3688.5 | 3688.5 | 3688.5 | 3688.5 |
| Profitable Demand Volume | 0 | 0 | 917.733 | 2133.48 | 1736.48 | 1865.48 | 0 | 0 | 0 | 0 | 0 | 2367.98 |
| Monthly CIF US$/Kg | 1.87 | 1.96 | 2.10 | 2.05 | 1.87 | 1.81 | 2.04 | 2.51 | 2.45 | 2.22 | 2.36 | 1.86 |
| Egypt CIF US$/Kg | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 | 0.91 |

**Figure A-17 UK Green Beans Profitable Demand**

## *Galia Melons*

Among products showing very rapid increase and great potential for WANA countries in the European markets are Galia melons. Major suppliers of melons to the EU market are Spain and Israel in addition to large volumes coming from Central America.

WANA countries has certain advantages among current suppliers and can serve the increasing demand through the best quality price combinations compared to any other competitor.

The following summarizes the melons market in Europe and potential for WANA countries .

***Germany***

Germany imports of Galia melons increased dramatically over recent years. Imports increased from about 30,000 MT per year up to almost 90,000 MT. As local production is non-existent, total German consumption will be supplied by imports.

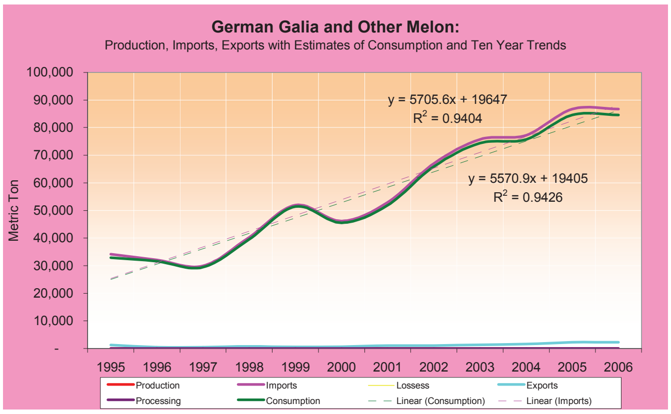



**Figure A-18 Germany Galia Melons Import Trends**

Spain is the major Galia melon supplier to the German market, however imports from far away countries such as Costa Rica and South Africa play a significant role. The market is unsaturated during the winter months from Nov. – April, which opens up excellent market opportunities for WANA countries .

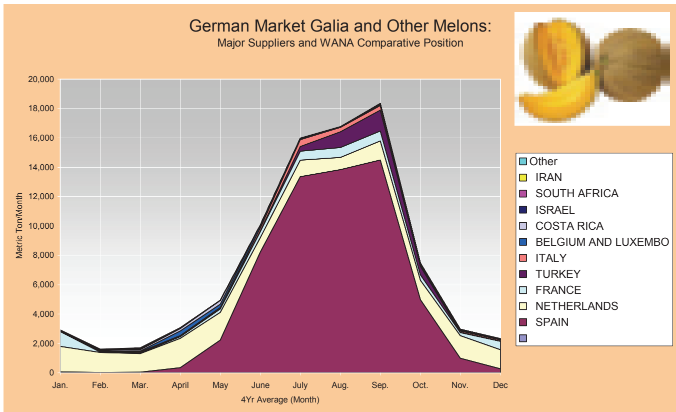
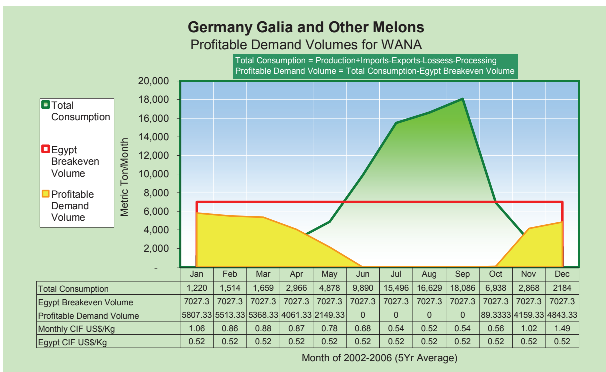



**Figure A-19 Germany Galia Melons Major Suppliers**

Germany offers serious suppliers with a market of more than 80 thousand metric tonnes during the winter season while prices never drop below the break-even prices.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Consumption | 1,220 | 1,514 | 1,659 | 2,966 | 4,878 | 9,890 | 15,496 | 16,629 | 18,086 | 6,938 | 2,868 | 2184 |
| Egypt Breakeven Volume | 7027.3 | 7027.3 | 7027.3 | 7027.3 | 7027.3 | 7027.3 | 7027.3 | 7027.3 | 7027.3 | 7027.3 | 7027.3 | 7027.3 |
| Profitable Demand Volume | 5807.33 | 5513.33 | 5368.33 | 4061.33 | 2149.33 | 0 | 0 | 0 | 0 | 89.3333 | 4159.33 | 4843.33 |
| Monthly CIF US$/Kg | 1.06 | 0.86 | 0.88 | 0.87 | 0.78 | 0.68 | 0.54 | 0.52 | 0.54 | 0.56 | 1.02 | 1.49 |
| Egypt CIF US$/Kg | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 |

**Figure A-20 Germany Galia Melons Profitable Demand**

### *The United Kingdom*

United Kingdom imports of Galia melons almost doubled during the analysis period, which reflects the consumption patterns of this high export potential product.

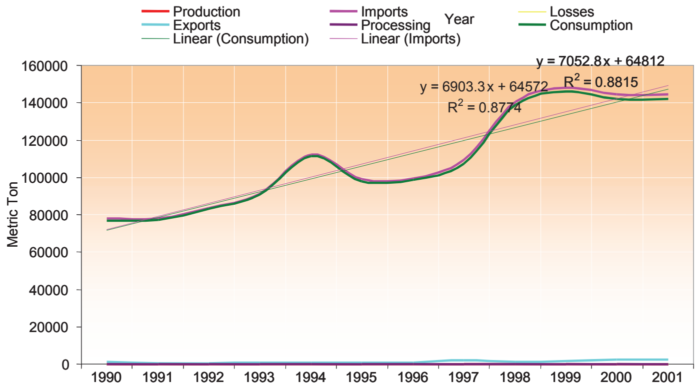



**Figure A-21 UK Galia Melons Import Trends**

Imports from Northern America dominate the market and compete head-to-head with Spanish product.

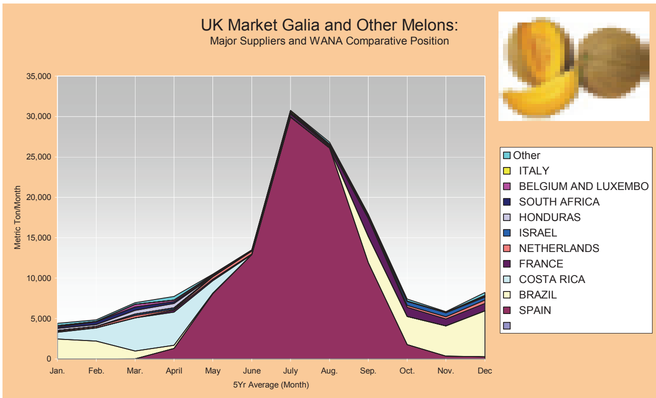
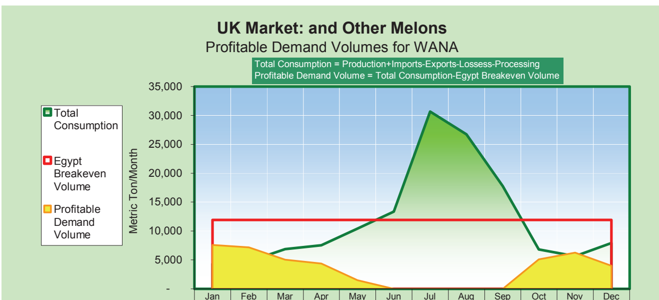



**Figure A-22 UK Galia Melons Major Suppliers**

### UK Galia Melons Profitable Demand

The United Kingdom offers and other serious competitors with a market of more than 50 thousand metric tonnes of Galia melons each year.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Consumption | 4,325 | 4,725 | 6,848 | 7,553 | 10,435 | 13,339 | 30,673 | 26,739 | 17,767 | 6,813 | 5,661 | 7936 |
| Egypt Breakeven Volume | 11901.2 | 11901.2 | 11901.2 | 11901.2 | 11901.2 | 11901.2 | 11901.2 | 11901.2 | 11901.2 | 11901.2 | 11901.2 | 11901.2 |
| Profitable Demand Volume | 7576.17 | 7176.17 | 5053.17 | 4348.17 | 1466.17 | 0 | 0 | 0 | 0 | 5088.17 | 6240.17 | 3965.17 |
| Monthly CIF US$/Kg | 1.16 | 1.16 | 1.09 | 0.89 | 0.69 | 0.62 | 0.47 | 0.53 | 0.60 | 0.73 | 0.97 | 0.82 |
| Egypt CIF US$/Kg | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 | 0.52 |

Month of 2002-2006 (5Yr Average)

**Figure A-23 UK Melon Market**

## *France*

### France Galia Melons Import Trends

French people prefer another type of melon called Charantee. Import trends of this type of melon showed significant increases during the last few years, especially during the period 1998 – 2001.

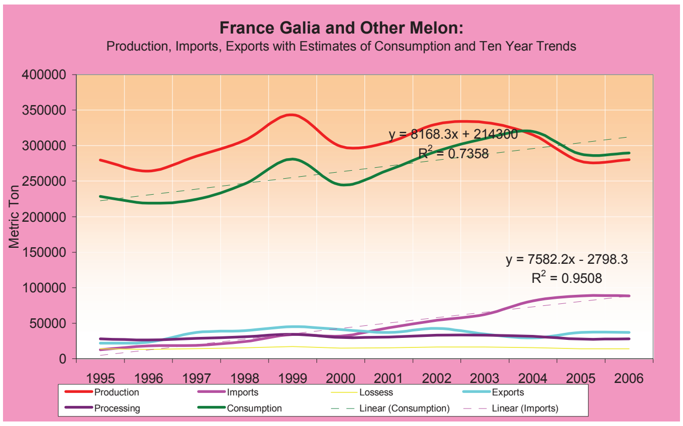
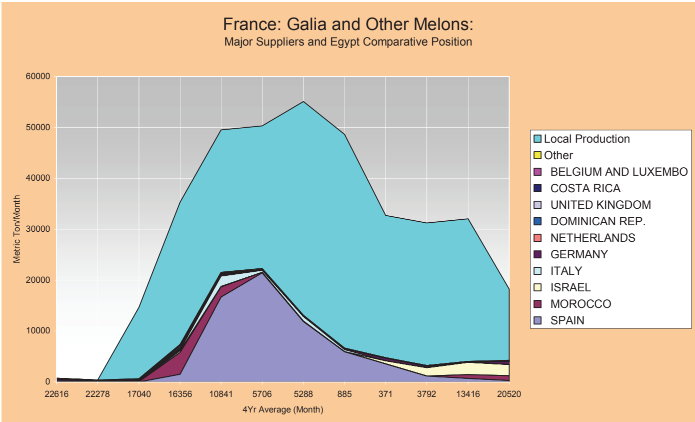
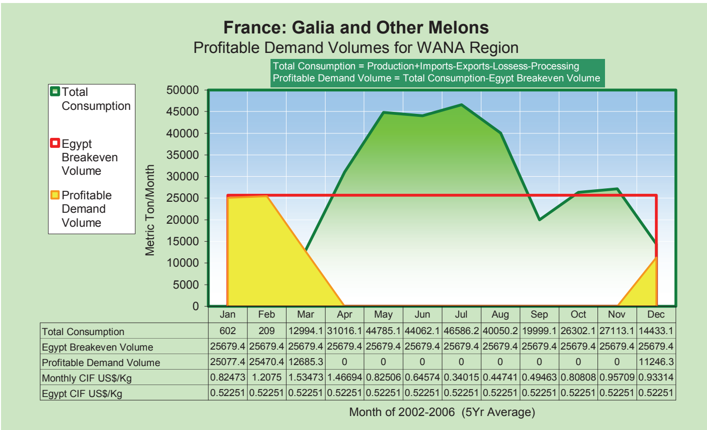



Figure A24 France melon import trend

Morocco is the most important Non-European melon supplier to the French market. However, significant volumes of melons are shipped to the French market from Central America.




France offers and other serious competitors a market with more than a 40 thousand metric tonne opportunity of Galia melons each year.




| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Consumption | 602 | 209 | 12994.1 | 31016.1 | 44785.1 | 44062.1 | 46586.2 | 40050.2 | 19999.1 | 26302.1 | 27113.1 | 14433.1 |
| Egypt Breakeven Volume | 25679.4 | 25679.4 | 25679.4 | 25679.4 | 25679.4 | 25679.4 | 25679.4 | 25679.4 | 25679.4 | 25679.4 | 25679.4 | 25679.4 |
| Profitable Demand Volume | 25077.4 | 25470.4 | 12685.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11246.3 |
| Monthly CIF US$/Kg | 0.82473 | 1.2075 | 1.53473 | 1.46694 | 0.82506 | 0.64574 | 0.34015 | 0.44741 | 0.49463 | 0.80808 | 0.95709 | 0.93314 |
| Egypt CIF US$/Kg | 0.52251 | 0.52251 | 0.52251 | 0.52251 | 0.52251 | 0.52251 | 0.52251 | 0.52251 | 0.52251 | 0.52251 | 0.52251 | 0.52251 |

A-26 France Galia Melons Profitable Demand

## *Analysis by Target Market*

The above analysis focuses on the market potential for selected commodities to show the exporter the highest potential markets for this specific product. However, in many cases it might be also useful to focus on specific market to estimate the export potential for this specific market for group of commodities. Unless the exporter is focusing only on one line item, analyzing the market potential for group of commodities will be of interest to the exporter.

The "profitable demand approach" or "the market window approach" could be used to estimate the market potential for group of commodities.

The following graphs summarizes the market potential for a group of high potential crops in both Germany – as the biggest market in Europe- and the U.K. –as the highest profitable market in terms of unit values. The U.K.

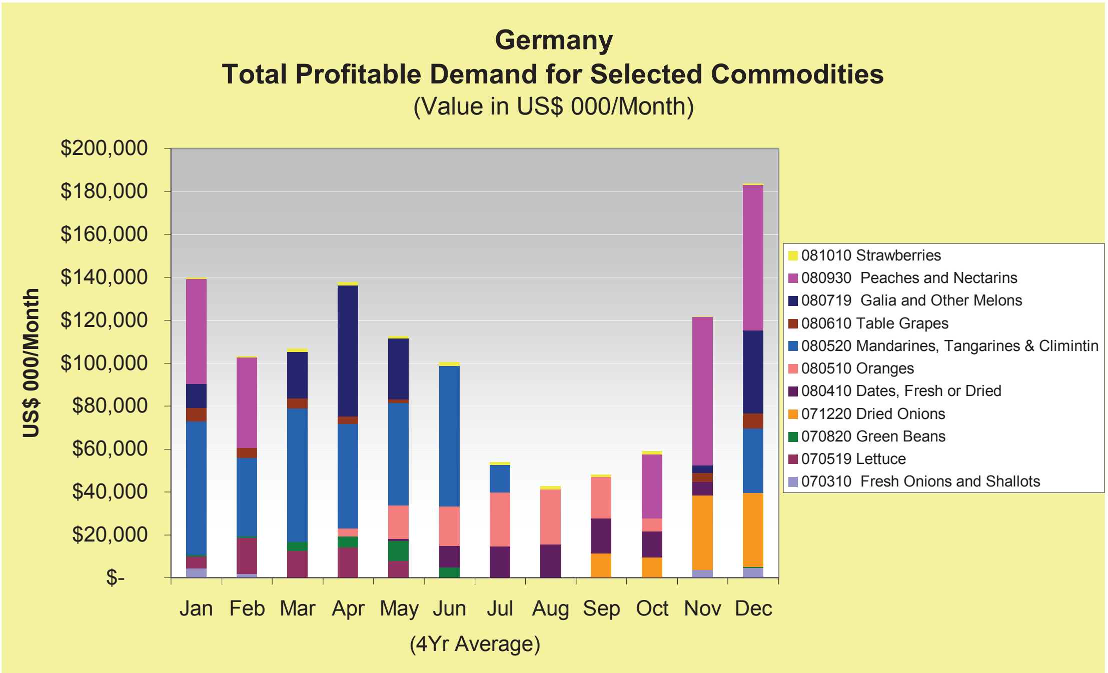



Figure A-27 Size of the German market for selected commodities

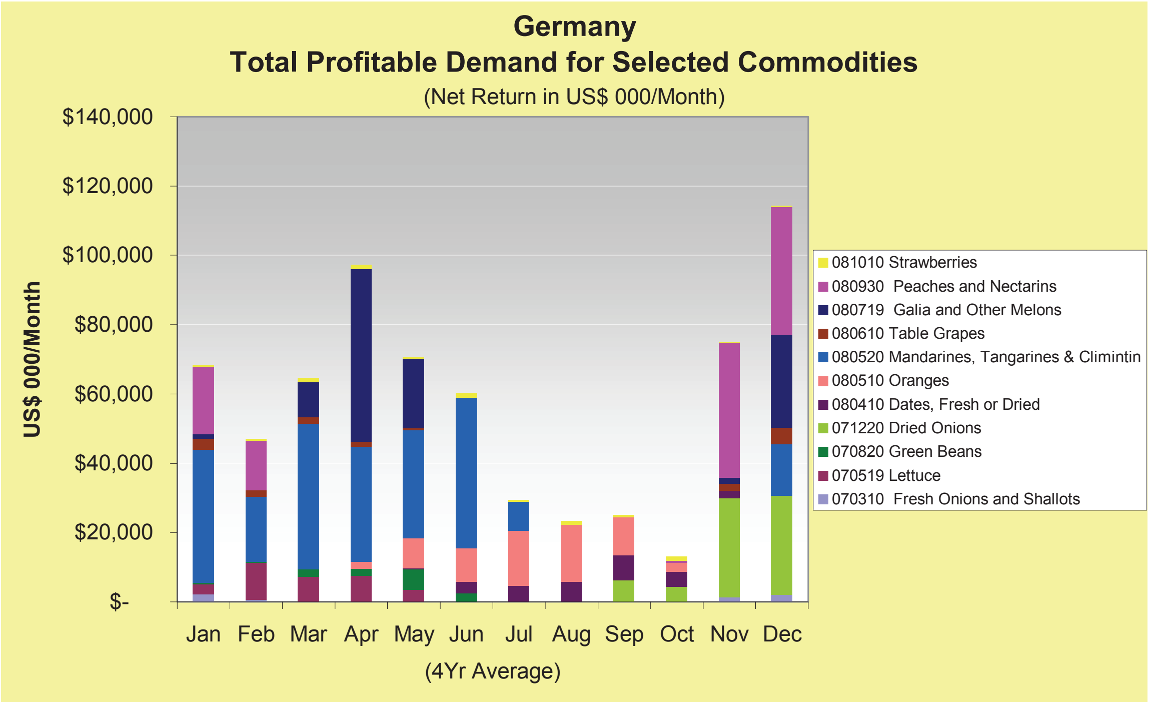
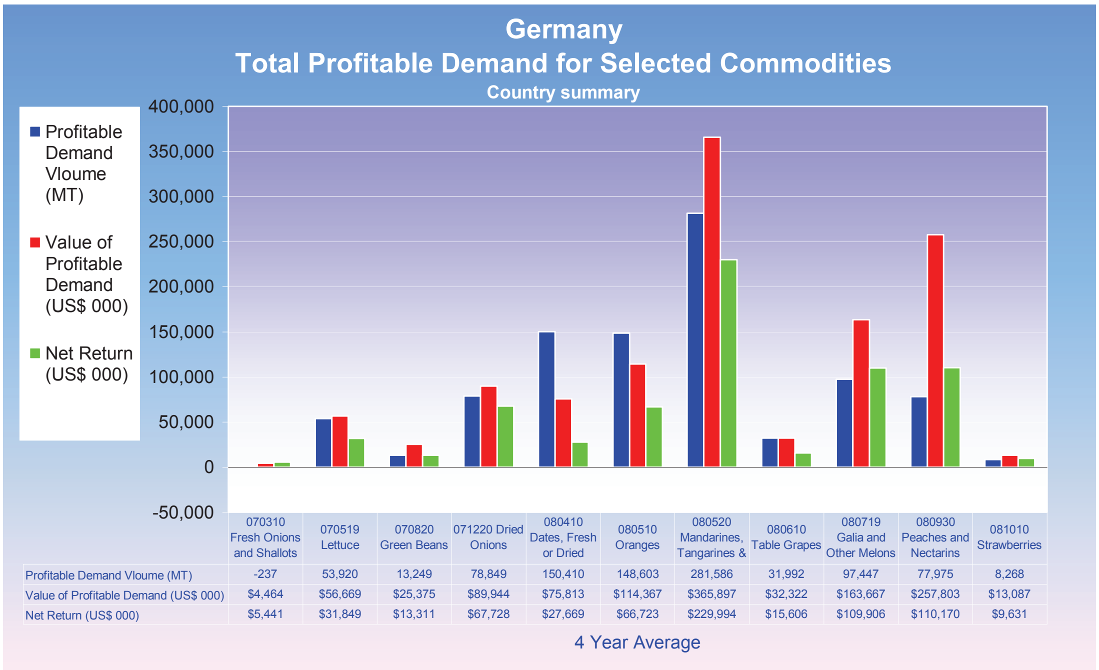



Figure A-28 Net return expected when focusing on the German market




| | 070310 Fresh Onions and Shallots | 070519 Lettuce | 070820 Green Beans | 071220 Dried Onions | 080410 Dates, Fresh or Dried | 080510 Oranges | 080520 Mandarines, Tangarines & | 080610 Table Grapes | 080719 Galia and Other Melons | 080930 Peaches and Nectarins | 081010 Strawberries |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Profitable Demand Vloume (MT) | -237 | 53,920 | 13,249 | 78,849 | 150,410 | 148,603 | 281,586 | 31,992 | 97,447 | 77,975 | 8,268 |
| Value of Profitable Demand (US$ 000) | $4,464 | $56,669 | $25,375 | $89,944 | $75,813 | $114,367 | $365,897 | $32,322 | $163,667 | $257,803 | $13,087 |
| Net Return (US$ 000) | $5,441 | $31,849 | $13,311 | $67,728 | $27,669 | $66,723 | $229,994 | $15,606 | $109,906 | $110,170 | $9,631 |

Figure A-29 German market summary

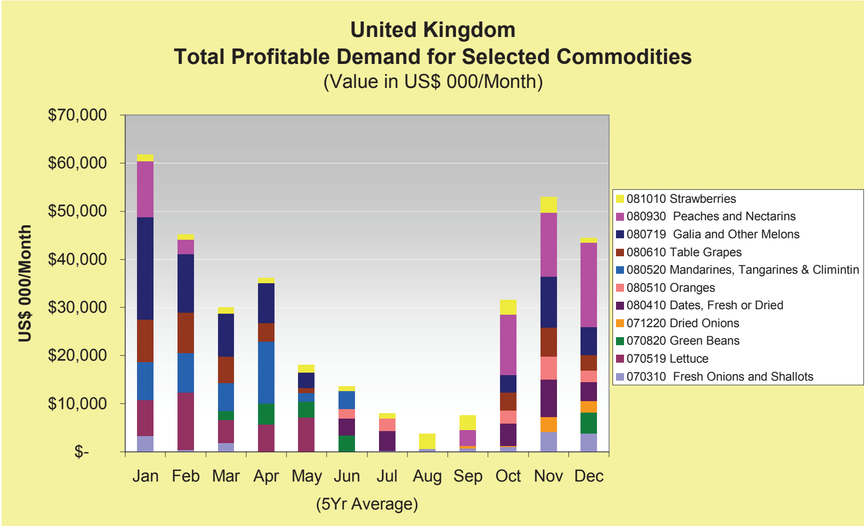



Figure A-30 Size of the U.K. market for selected commodities – Value terms

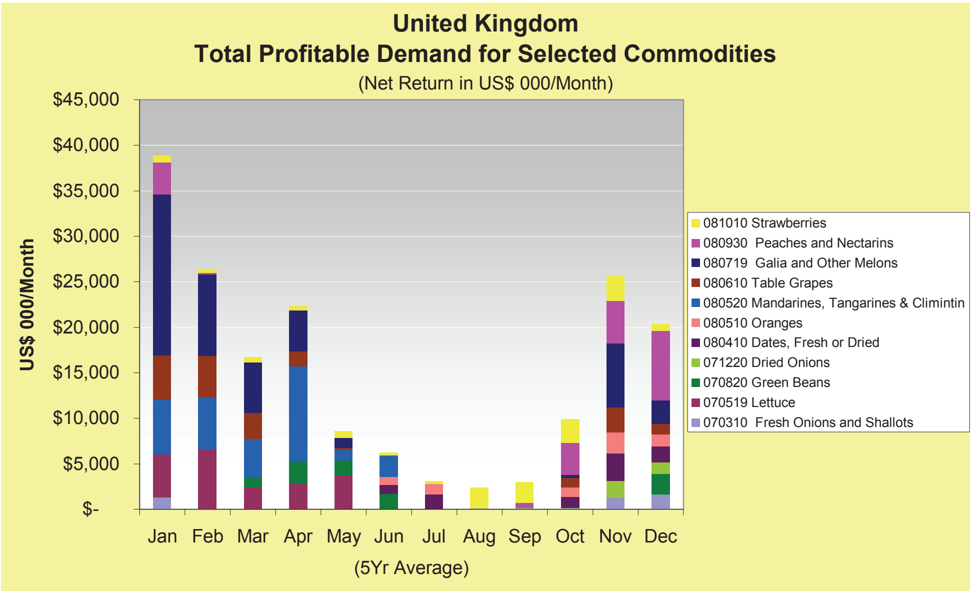
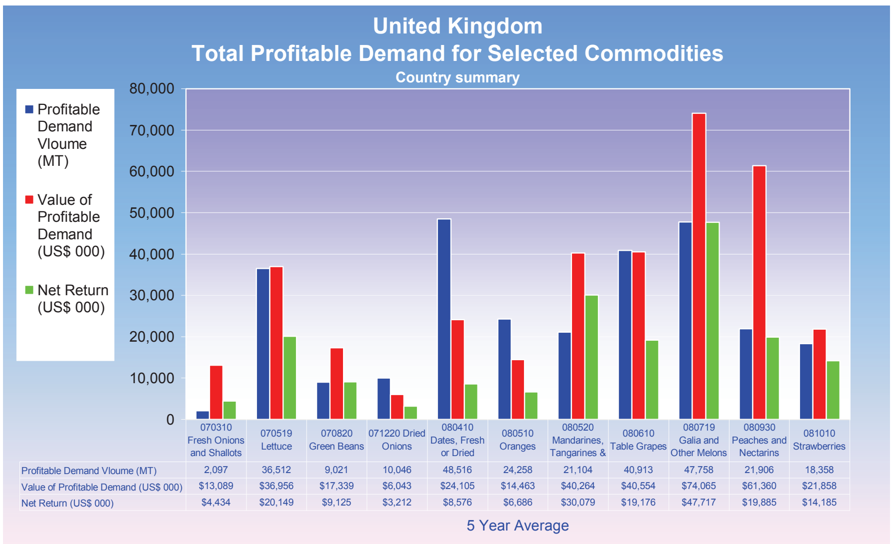



Figure A-31 Size of the U.K. market for selected commodities – Net profit




| | 070310 Fresh Onions and Shallots | 070519 Lettuce | 070820 Green Beans | 071220 Dried Onions | 080410 Dates, Fresh or Dried | 080510 Oranges | 080520 Mandarines, Tangarines & | 080610 Table Grapes | 080719 Galia and Other Melons | 080930 Peaches and Nectarins | 081010 Strawberries |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Profitable Demand Vloume (MT) | 2,097 | 36,512 | 9,021 | 10,046 | 48,516 | 24,258 | 21,104 | 40,913 | 47,758 | 21,906 | 18,358 |
| Value of Profitable Demand (US$ 000) | $13,089 | $36,956 | $17,339 | $6,043 | $24,105 | $14,463 | $40,264 | $40,554 | $74,065 | $61,360 | $21,858 |
| Net Return (US$ 000) | $4,434 | $20,149 | $9,125 | $3,212 | $8,576 | $6,686 | $30,079 | $19,176 | $47,717 | $19,885 | $14,185 |

Figure A-32 U.K. Market potential summary

# CHAPTER SIX

# ANNEXES

# Grouping of compatible horticultural commodities

Horticultural commodities should be stored and transported only with compatible commodities to avoid deterioration and losses. The following are groupings of compatible commodities that can be either stored or transported together at the temperature and relative humidity conditions indicated

**Group 1**. *Fruits and vegetables, 0-2°C, 90-95% relative humidity. Several are ethylene producers.*
Apples, apricots, Asian pears, Barbados cherry, beets (topped), berries (except cranberries), caimito, cashew apple, cherries, coconuts, currants, cut fruits, dates, figs (not with apples), gooseberry, grapes (without sulfur dioxide), horseradish, kohlrabi, leeks, longan, loquat, lychee, mushrooms, nectarines, parsnips, peaches, pears, persimmons, plums, pomegranates, prunes, quinces, radishes, raspberry, strawberry, rutabagas, turnips

**Group 2**. *Fruits and vegetables, 0-2°C, 90-100% relative humidity. Many are sensitive to ethylene.*
Alfalfa sprouts, amaranth, anise, artichokes, arugula, asparagus, bean sprouts, beets, Belgian endive, berries (except cranberries), bok choy, broccoli, Brussels sprouts, cabbage, carrots, cauliflower, celeriac, celery, chard, cherries, sweet corn, cut vegetables, daikon, endive, escarole, grapes (without sulphur dioxide), horseradish, Jerusalem artichoke, kailon, kale, kiwifruit, kohlrabi, leafy greens, leeks (not with figs or grapes), lettuce, lo bok, mint, mustard greens, green onions (not with figs, grapes, mushrooms, rhubarb, or corn), parsley, parsnips, peas, pomegranates, radicchio, rhubarb, rutabagas, salsify, scorzonera, shallot, snow peas, spinach, turnips, waterchesnut, watercress

**Group 3**. *Fruits and vegetables, 0-2°C, 65-75% relative humidity,*
Dry onion, garlic

**Group 4**. *Fruits and vegetables, 5°C, 90-95% relative humidity,*
Caimito, cantaloupes, clementine, cranberries, lemons, lychees, kumquat, mandarin, oranges, pepino, tamarillo, tangelos, tangerines, ugli fruit, yucca root

**Group 5**. *Fruits and vegetables, 7-10°C, 85-90% relative humidity, sensitive to chilling injury, many are sensitive to ethylene.*
Babaco, basil, beans, cactus stems (nopal), prickly pears, caimito, calamondin, chayote, cowpea, cranberry, cucumber, custard apple, durian, eggplant, feijoa, granadilla, grapefruit, guava, haricot vert, kiwano, kumquat, lemon, lime, long bean, malanga, mandarin, okra, olive, orange, passion fruit, pepino, peppers, pineapple, potatoes, pummelo, sugar apple, summer squash (soft shell), tamarind, tangelo, tangerine, taro root, tomatillo, ugli fruit, watermelon, winged bean

**Group 6**. *Fruits and vegetables, 13-15°C, 85-90% relative humidity, chilling sensitive, many produce high concentration of ethylene.*
Atemoya, avocados (certain cultivars), babaco, bananas, bitter melon, black sapote, boniato, breadfruit, canistel, carambola, cassava, cherimoya, coconuts, feijoa, ginger root, granadilla, grapefruit, guava, jaboticaba, jackfruit, langsat, lemons, limes, mamey, mangoes, mangosteen, melons (except cantaloupes), papayas, passionfruit, pineapple, plantain, pumpkin, rambutan, santol, sapodilla, sapote, soursop, sugar apple, winter squash, tomatillos, ripe tomatoes, yam

**Group 7**. *Fruits and vegetables, 18-21°C, 85-90% relative humidity.*
Jicama, sweet potatoes, mature green tomatoes, watermelon, white sapote, yams

**Group 8**. *Flowers and florist greens, 0-2°C, 90-95% relative humidity*
Aadiantum, allium, aster (China), bouvardia, carnation, cedar, chrysanthemum, crocus, cymbidium orchid, dagger and wood, ferns, freesia, galax, gardenia, ground pine, hyacinth, ilex (holy), iris (bulbous), juniper, lily, lily-of-the-valley, mistletoe, mountain-laurel, narcissus, peony (tight buds), ranunculus, rhododendren, rose, salal (lemon leaf), squill, sweet pea, tulip, vaccinium (huckleberry), woodwardia fern

**Group 9**. *Flowers and florist greens, 4.5°C, 90-95% relative humidity.* Acacia, adiantum (maidenhair), alstromeria, anemone, aster (China), asparagus (plumosa, sprenger), buddleia, buxus (boxwood), calendula, calla, candytuft, caemellia, clarkia, colombina, coreopsis, cornflower, cosmos, croton, dahlia, daisies, delphinium, dracaena, eucalyptus, feverfew, forgot-me-not, foxglove, gaillardia, gerbera, gladiolus, gloriosa, gypsophilla, heather, hedera, luine, magnolia, marigolds, mignonette, philodendren, phlox, pittosporum, poppy, pothos, primrose, protea, , ranunculus, scotch-broomern, snapdragon, snowdrop, statice, stephanotis, stevia, stock, strawflower, violet, woodwardia fern, zinnia

**Group 10**. *Flowers and florist greens, 7-10°C, 90-95% relative humidity.*
Anemone, bird-of-paradise, camellia, chamaedora, eucharis, gloriosa, godetia, palm, podocarpus, sweet William

**Group 11**. *Flowers and florist greens, 13-15°C, 90-95% relative humidity.*
Anthurium, ginger, diffenbachia, heliconia, staghorn fern, poinsetta

## Commodities sensitive to chilling injury

Several horticultural commodities, especially from tropical and subtropical origin are susceptible to low temperature, and therefore care should be taken when assigning the optimum temperature for their storage and shipping. The following is a list of some chilling-senstive commodities.

Atemoya, avcados, babaco, bananas, beans, bitter melons, black sapote, boniato, breadfruit, calabaza, calamondin, canistel, cantaloupe, carambola, chayote, cherimoya, cranberries, cucumbers, custard apple, eggplant, feijoa, ginger root, granadilla, grapefruit, guavas, haricot vert, jaboticba, jackfruit, jicama, kiwano, langsat, lemons, limes, malanga, memey, mangoes, mangosteen, melons, okra, olive, oranges, papaya, passionfruit, pepino, peppers, pineapples, plantain, pomegranates, potatoes, potted plants, pummelo, pumpkins, rambutan, santol, sapodilla, soursop, squash, sugar apple, sweet potatoes, tamarillo, tamarind, taro root, tomatillo, tomatoes, tropical flowers, ugli fruit, watermelon, white sapote, yam.

## Ethylene highly produced commodities

Horticultural commodities vary in their capacity to produce ethylene. The following is a list of some of the ethylene highly produced commodities, which should be taken in consideration especially during mixed storage or shipping with commodities that are sensitive to ethylene.

Apples, apricots, avocados, banana (ripening), cantaloupe, cherimoya, figs, guava, honeydew melons, ripe kiwifruit, mamey, mangoes, mangosteen, nectarines, papayas, passion fruit, peaches, pears, persimmons, plantains, plums, prunes, quinces, rambutan, tomatoes

## Ethylene sensitive commodities

The following is a list of some horticultural commodities that are sensitive to exposure to ethylene that should be take in consideration especially during mixed storage or transport, and especially with commodities that produce high concentration of this gas.

Banana (unripe), Belgian endive, broccoli, Brussels sprouts, cabbage, carrots, cauliflower, chard, cucumbers, cut flowers, eggplant, florist greens, green beans, kiwifruit (unripe), leafy greens, lettuce, okra, parsley, peas, peppers, potted plants, spinach, squash, sweet potatoes, watercress, watermelon, yams.

## Pre-cooling methods for some horticultural commodities

The following is a list of the ideal pre-cooling methods that can be used for each of the listed horticultural commodities.

R = Room cooling, F = Forced air cooling, H = hydro-cooling, V = Vacuum cooling, I = Icing.

Apples: R, F, H
Artichoke: H, I
Asparagus: H, I
Avocados: F
Beans, snap: R, F, H
Beans, butter: R, F, H
Beets, topped: R
Berries: F
Blueberries: R, F
Brambles: R, F
Broccoli: I
Cabbage: R, F
Cantaloupe: H, I
Cucumbers: F, H
Cut flowers: F, R
Eggplant: R, F
Grapes: F
Green onions: H, I
Leafy greens: H, I
Lettuce: V
Mangoes: F
Mushrooms: F
Okra: R, F
Papayas: F, R
Peaches: F, H
Peas: F, H
Peas: F, H
Peppers: R, F
Potatoes: R, F
Potted plants: R
Squash: R, F
Strawberries: R, F
Sweet corn: H, I
Tomatoes: R, F
Turnips: R
Watermelons: R

**Odor-producing and absorbing- commodities**. This table includes a list of commodities that can produce certain odors and those that can absorb these odors, which should be considered when storing and transporting mixed loads.

| **Odor produced by** | **Absorbed by** |
|---|---|
| Apples | cabbage, carrots, celery, figs, onions, meat, eggs, dairy products |
| Avocados | Pineapples |
| Carrots | Celery |
| Citrus fruit | Meat, eggs, dairy products |
| Ginger roots | Eggplants |
| Grapes, $SO_2$ treated | Almost all other fruits and vegetables |
| Leeks | Figs, grapes |
| Onions, dry | Apples, celery, pears |
| Onions, green | Corn, figs, grapes, mushrooms, rhubarb |
| Pears | Cabbage, carrots, celery, onions, potatoes |
| Potatoes | Apples, pears |
| Peppers, green | Pineapples |
| Strongly scented vegetables | Citrus fruit |

## Recommended conditions for handling of horticultural commodities

| **Common name** | **Scientific name** | **Temperature (ºC)** | **Relative humidity (%)** | **Ethylene production *** | **Sensitivity to ethylene**** | **Posthar-vest life** |
|---|---|---|---|---|---|---|
| Acerola | *Malpighia glabra* | 0 | 85 - 90 | | | 6 – 8 weeks |
| African horned melon; kiwano | *Cucumis africanus* | 13 - 15 | 90 | L | M | 6 months |
| Alfalfa sprouts | *Medicago sativa* | 0 | 95 - 100 | | | 7 days |
| Amaranth; Pigweed | *Amaranthus spp.* | 0 - 2 | 95 - 100 | VL | M | 10 – 14 days |
| American grape | *Vitis labrusca* | -1- -0.5 | 90 - 95 | VL | L | 1 – 6 months |
| Apple | *Malus pumila* | - 1.1 | 90 - 95 | M | H | 3 – 6 months |
| Apple chilling sensitive | *cv. Yellow, Newton, Grimes, Golden, McIntosh* | 4 | 90 - 95 | M | H | 1 – 2 months |
| Apricot | *Prunus armeniaca* | -0.5 - 0 | 90 - 95 | M | H | 1 – 3 weeks |
| Arugula | *Eruca versicaria var. sativa* | 0 | 95 - 100 | VL | H | 7 – 10 days |
| Asian Pear, Nashi | *Pyrus serotina; P. Pyrifolia* | 1 | 90 - 95 | H | H | 4 – 6 months |
| Asparagus green, white | *Asparagus officinalis* | 2.5 | 95 - 100 | VL | M | 2 – 3 weeks |
| Atemoya | *Annona squamosa x A. cherimola* | 13 | 85 - 90 | H | H | 4 – 6 weeks |
| Avocado Fuchs Pollock | *Persea americana* | 13 | 85 - 90 | H | H | 2 weeks |
| Avocado Fuerte Hass | | 3 - 7 | 85 - 90 | H | H | 2 – 4 weeks |
| Avocado Lula Booth | | 4 | 90 - 95 | H | H | 4 – 8 weeks |
| Banana | *Musa paradisiaca var. sapientum* | 13 - 15 | 90 - 95 | M | H | 1 – 4 weeks |
| Basil | *Ocimum basilicum* | 10 | 90 | VL | H | 7 days |
| Bean sprouts | *Phaseolus sp.* | 0 | 95 - 100 | | | 7 – 9 days |
| Beet bunched | *Beta vulgaris* | 0 | 98 - 100 | VL | L | 10 – 14 days |
| Beet, topped | | 0 | 98 - 100 | VL | L | 4 months |
| Belgian endive; witloof chicory | *Cichorium intybus* | 2 - 3 | 95 - 98 | VL | M | 2 – 4 |
| Bell pepper, paprika | *Capsicum annuum* | 7 - 10 | 95 | L | L | 2 – 3 weeks |
| Bittermelon; Bitter gourd | *Momordica charantia* | 10 - 12 | 85 - 90 | L | M | 2 – 3 weeks |
| Black salsify; Scorzonera | *Scorzonera hispanica* | 0 -1 | 95 - 98 | VL | L | 6 months |
| Blackberries | *Rubus spp.* | -0.5 - 0 | 90 - 95 | L | L | 3 – 6 days |
| Blak sapote | *Diospyrus ebenaster* | 13 - 15 | 85 - 90 | | | 2 – 3 weeks |

| | | | | | | |
|---|---|---|---|---|---|---|
| Blood orange | *Citrus sinensis* | 4 - 7 | 90 - 95 | | | 3 – 8 weeks |
| Blueberries | *Vaccinium corymbosum* | -0.5 - 0 | 90 - 95 | VL | L | 10 – 18 days |
| Bok choy | *Brassica chinensis* | 0 | 95 - 100 | VL | H | 3 weeks |
| Breadfruit | *Artocarpus altilis* | 13 - 15 | 85 - 90 | | | 2 – 6 weeks |
| Brócoli | *B. oleracea var. Italica* | 0 | 95 - 100 | VL | H | 10-14 days |
| Brussel sprouts | *B. oleracea var. Gemnifera* | 0 | 95 - 100 | VL | H | 3 – 5 weeks |
| Bunched carrots | *Daucus carota* | 0 | 98 - 100 | VL | H | 10 – 14 days |
| Cactus fruit; Prickly pear fruit | *Opuntia spp.* | 5 | 85 - 90 | VL | M | 3 weeks |
| Cactus leaves, nopalitos | *Opuntia spp.* | 5 - 10 | 90 - 95 | VL | M | 2 – 3 weeks |
| Caimito, star apple | *Chrysophyllu m cainito* | 3 | 90 | | | 3 weeks |
| Calamondin orange | *Citrus reticulata x Fortunella spp.* | 9 - 10 | 90 | | | 2 weeks |
| Canistel eggfruit | *Pouteria campechiana* | 13 - 15 | 85 -90 | | | 3 weeks |
| Cantaloupes and other netted melons | *Cucurbita melo var. reticulatus* | 2 - 5 | 95 | H | M | 2 – 3 weeks |
| Carambola, Starfruit | *Averrhoa carambola* | 9 - 10 | 85 - 90 | | | 3 – 4 weeks |
| Carrots, topped | *Daucus carota* | 0 | 98 - 100 | VL | H | 6 – 8 months |
| Casaba melon | *Cucurbita melo* | 7 - 10 | 85 - 90 | L | L | 3 – 4 weeks |
| Cashew apple | *Anacardium occidentale* | 0 - 2 | 85 - 90 | | | 5 weeks |
| Cassava, Yucca manioc | *Manihot esculenta* | 0 - 5 | 85 - 90 | VL | L | 1 – 2 months |
| Cauliflower | *Brassica oleracea* | 0 | 95 - 98 | VL | H | 3 – 4 weeks |
| Celeriac | *Apium graveolens car. Rapaceum* | 0 | 98 - 100 | VL | L | 6 – 8 months |
| Celery | *Apium graveLens var. Dulce* | 0 | 98 - 100 | VL | M | 1 – 2 months |
| Chard | *Beta vulgaris var. Cicla* | 0 | 95 - 100 | VL | H | 10 – 14 days |
| Chayote | *Sechium edule* | 7 | 85 - 90 | | | 4 – 6 weeks |
| Cherimoya; custard apple | *Annona cherimola* | 13 | 90 - 95 | H | H | 2 – 4 weeks |
| Cherries, sour | *Pranus cerasus* | 0 | 90 - 95 | | | 3 – 7 days |
| Cherries, sweet | *Pranus avium* | -1 to 0 | 90 - 95 | | | 2 – 3 weeks |
| Chinese broccoli; gailan | *Brassica alboglabra* | 0 | 95 - 100 | VL | H | 10 – 14 days |
| Chinese cabbage; Napa cabbage | *Brassica campestris var. Pekinensis* | 0 | 95 - 100 | VL | H | 2 – 3 months |

| | | | | | | |
|---|---|---|---|---|---|---|
| Chinese/ Japanese artichoke | *Stachys affinia* | 0 | 90 - 95 | VL | L | 1 – 2 weeks |
| Chives | *Allium schoenoprasum* | 0 | 95 - 100 | VL | M | 2 – 3 weeks |
| Chives | *Allium shoenoprasum* | 0 | 95 - 100 | L | M | |
| Cilantro, Chinese parsley | *Coriandrum sativum* | 0.2 | 95 - 100 | VL | H | 2 weeks |
| Coconut | *Cocos mucifera* | 0 - 2 | 89 - 85 | | | 1 – 2 months |
| Collards, Kale | *B. oleracea var. Acephala* | 0 | 95 - 100 | VL | H | 10 – 14 days |
| Corn sweet and baby | *Sea mays* | 0 | 95 - 98 | VL | L | 5 – 8 days |
| Cranberry | *Vaccinium macrocrpon* | 2 - 5 | 90 - 95 | L | L | 8 – 16 weeks |
| Crenshaw melon | *Cucurbita melo* | 7 - 10 | 85 - 90 | M | H | 2 – 3 weeks |
| Cucumber | *Cucunicus sativus* | 10 - 12 | 85 - 90 | L | H | 10 –14 days |
| Currants | *Ribes sativum; R. Nigrum; R. rubrum* | -0.5 - 0 | 90 - 95 | L | L | 1 – 4 weeks |
| Daikon; oriental radish | *Raphanus sativus* | 0 - 1 | 95 - 100 | VL | L | 4 months |
| Date | *Phoenix dactylifera* | -18 - 0 | 75 | VL | L | 6 – 12 months |
| Dill | *Anethum graveolens* | 0 | 95 - 100 | VL | H | 1 – 2 weeks |
| Durian | *Durio zibethinus* | 4 - 6 | 85 - 90 | | | 6 – 8 weeks |
| Early crop cabbage | *B. oleracea var. capitata* | 0 | 98 - 100 | VL | H | 3 – 6 weeks |
| Endive escarole | *Cichorium endivia* | 0 | 95 - 100 | VL | M | 2 – 4 weeks |
| Epazote | *Chenepodium ambrosioides* | 0 - 5 | 90 - 95 | VL | M | 1 – 2 weeks |
| Faba, Broad beans | *Vicia faba* | 0 | 90 - 95 | | | 1 – 2 weeks |
| Feijoa, pineapple guava | *Feijoa sellowiana* | 5 - 10 | 90 | M | L | 2 – 3 weeks |
| Fennel; Anise | *Foeniculum vulgare* | 0 - 2 | 90- 95 | H | | 2 – 3 weeks |
| Fig fresh | *Ficus carica* | -0.5 - 0 | 85 - 90 | M | L | 7 – 10 days |
| Fuyu persimmon | *Dispyros kaki* | 10 | 90 - 95 | L | H | 1 – 3 months |
| Garlic | *Allium sativum* | 0 | 65 - 70 | VL | L | 6 –7 months |
| Ginger | *Zingiber officinale* | 13 | 65 | VL | L | 6 months |
| Globe artichoke | *Cynara acolymus* | 0 | 95 - 100 | VL | L | 2 – 3 weeks |
| Gooseberry | *Ribes grossularia* | -0.5 - 0 | 90 - 95 | L | L | 3 – 4 weeks |

| | | | | | | |
|---|---|---|---|---|---|---|
| Grape | *Vitis vinifera* | -0.5 - 0 | 90 - 95 | VL | L | 2 – 8 weeks |
| Grapefruit from dry areas | *Citrus paradisi* | 14 - 15 | 85 - 90 | VL | M | 6 – 8 weeks |
| Grapefruit from humid areas | *Citrus paradisi* | 10 - 15 | 85 - 90 | VL | M | 6 – 8 weeks |
| Green onions | *Allium cepa* | 0 | 95 - 100 | L | H | 3 weeks |
| Guava | *Psidium guajava* | 5 - 10 | 90 | L | M | 2 – 3 weeks |
| Hachiya Persimmon | *Dispyros kaki* | 5 | 90 - 95 | L | H | 2 – 3 months |
| Honeydew, orange – flesh melons | *Cucrbita melo* | 5 - 10 | 85 - 90 | M | H | 3 – 4 weeks |
| Horseradish | *Armoracia rusticana* | -1 a 0 | 98 - 100 | VL | L | 10 – 12 months |
| Hot peppers, Chiles | *Capsicum annuum and C. Frutescens* | 5 - 10 | 85 - 95 | L | M | 2 – 3 weeks |
| Jaboticaba | *Myrciaria cauliflora; Eugenia cauliflora* | 13 - 15 | 90 - 95 | | | 2 – 3 days |
| Jackfruit | *Artocarpus heterophyllus* | 13 | 85 - 90 | M | M | 2 – 6 weeks |
| Jerusalem artichoke | *HeLianthus tuberosus* | -0.5-0 | 90 - 95 | VL | L | 4 months |
| Jicama, Yambean | *Pachyrrhizus erosus* | 13 - 18 | 85 - 90 | VL | L | 1 – 2 months |
| Jujube; Chinese date | *Ziziphus jujuba* | 2.5 - 10 | 85 - 90 | L | M | 1 month |
| Kiwifruit; Chinese gooseberry | *Actinidia chinensis* | 0 | 90 - 95 | L | H | 3 – 5 months |
| Kohlrabi | *B. oleracea var. Gongylodes* | 0 | 98 - 100 | VL | L | 2 – 3 months |
| Kumquat | *Fortunella japonica* | 4 | 90- 95 | | | 2 – 4 weeks |
| Langsat Lanzone | *Aglaia sp.; Lansium sp.* | 11 - 14 | 85 - 90 | | | 2 weeks |
| Late cabbage | *B. oleracea var. capitata* | 0 | 95 - 100 | VL | H | 5 – 6 months |
| Leek | *Allium porrum* | 0 | 95 - 100 | VL | M | 2 months |
| Lemon | *Citrus limon* | 10 - 13 | 85 - 90 | | | 1 – 6 months |
| Lettuce | *Lactuca sativa* | 0 | 98 - 100 | VL | H | 2 – 3 weeks |
| Lima beans | *Phaseolus lunatus* | 5 - 6 | 95 | L | M | 5 – 7 days |
| Lime, Mexican, Tahiti or Persian | *Citrus aurantifolia; C. Latifolia* | 9 - 10 | 85 - 90 | | | 6 – 8 weeks |
| Long bean yard-long bean | *Vigna sesquipedalis* | 4 - 7 | 90 - 95 | L | M | 7 – 10 days |

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|---|---|---|---|---|---|---|
| Longan | *Dimocarpus Longan = Euphoria Longan* | 1 - 2 | 90 - 95 | | | 3 – 5 weeks |
| Loquat | *Eriobotrya japonica* | 0 | 90 | | | 3 weeks |
| Luffa; Chinese okra | *Luffa spp.* | 10 - 12 | 90 - 95 | L | M | 1 – 2 weeks |
| Lychee, Litchi | *Litchi chinenesis* | 1 - 2 | 90 - 95 | M | M | 3 – 5 weeks |
| Malanga; Tania, New cocoyam | *Xanthosoma sagittifolium* | 7 | 70 - 80 | VL | L | 3 months |
| Mamey sapote | *Calocarpum mammosum* | 13 - 15 | 90 - 95 | H | H | 2 – 3 weeks |
| Mango | *Mangifera indica* | 13 | 85 - 90 | M | M | 2 – 3 weeks |
| Mangosteen | *Garcinia mangostana* | 13 | 85 - 90 | M | A | 2 – 4 weeks |
| Mature onion bulbs | *Allium cepa* | 0 | 65 - 70 | VL | L | 1 – 8 months |
| Mint | *Mentha spp.* | 0 | 95 - 100 | VL | H | 2 – 3 wks weeks |
| Mushrooms | *Agaricus; other genera* | 0 | 90 | VL | M | 7 – 14 days |
| Mustard greens | *Brassica juncea* | 0 | 90 - 95 | VL | H | 7 – 14 days |
| Nectarine | *Prunus persica* | -0.5 - 0 | 90 - 95 | M | H | 2 – 4 weeks |
| Okra | *Abelmoschus esculentus* | 7 - 10 | 90 - 95 | L | M | 7 – 10 days |
| Olives, fresh | *Olea europea* | 5 - 10 | 85 - 90 | L | M | 4 – 6 weeks |
| Orange | *Citrus sinensis* | | | | | |
| Orange from dry areas | *Citrus sinensis* | 3 - 9 | 85 - 90 | VL | M | 3 – 8 weeks |
| Orange from Fl. Humid regions | *Citrus sinensis* | 0 - 2 | 85 - 90 | VL | M | 8 – 12 semanas |
| Oregano | *Origanum vulgare* | 0 - 5 | 90 - 95 | VL | M | 1 – 2 weeks |
| Papaya | *Carica papaya* | 7 - 13 | 85 - 90 | | | 1 – 3 weeks |
| Parsley | *Petroselinum crispum* | 0 | 95 - 100 | VL | H | 1 – 2 months |
| Parsnips | *Pastinaca sativa* | 0 | 95 - 100 | VL | H | 4-6 months |
| Passion fruit | *Passiflora spp.* | 10 | 85 - 90 | VH | M | 3 – 4 weeks |
| Peach | *Prunus persica* | -0.5 - 0 | 90 - 95 | H | H | 2 – 4 weeks |
| Pear (American) | *Pyrus communis* | -1.5 to 0.5 | 90 - 95 | H | H | 2 – 7 months |
| Peas, pod | *Pisum sativum* | 0 | 95 - 98 | VL | M | 1 – 2 weeks |
| Pepino, melon pear | *Solanum muricatum* | 5 - 10 | 95 | L | M | 4 weeks |
| Perilla, Shiso | *Perilla frutenses* | 10 | 95 | VL | M | 7 days |
| Persian | *Cucrbita melo* | | 85 - 90 | M | H | 2 – 3 weeks |
| Pineapple | *Ananas* | 7 - 13 | 85 - 90 | L | L | 2 – 4 weeks |
| Plantain | *Musa paradisiaca var. paradisiaca* | 13 -15 | 90 - 95 | L | H | 1 – 5 weeks |

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|---|---|---|---|---|---|---|
| Plums and prunes | *Prunus domestica* | -0.5 - 0 | 90 - 95 | M | H | 2 – 5 weeks |
| Pomegranate | *Punica granatum* | 5 | 90 - 95 | | | 2 – 3 months |
| Potato, early crop | *Solanum tuberosum* | 10 - 15 | 90 - 95 | VL | M | 10 – 14 days |
| Potato, late crop | *Solanum tuberosum* | 4 - 12 | 95 - 98 | VL | M | 5 – 10 months |
| Pummelo | *Citrus grandis* | 7 - 9 | 85 - 90 | | | 12 weeks |
| Quince | *Cydonia oblonga* | -0.5 - 0 | 90 | L | H | 2 – 3 months |
| Raddichio | *Cichorium intylus* | 0 - 1 | 95 - 100 | | | 3 – 4 weeks |
| Radish | *Raphanus sativus* | 0 | 95 - 100 | VL | L | 1 – 2 months |
| Radish sprouts | *Raphanus sp.* | 0 | 95 - 100 | | | 5 –7 |
| Rambutan | *Nephelium lappaceum* | 12 | 90 - 95 | H | H | 1 – 3 weeks |
| Raspberries | *Rubus idaeus* | -0.5 - 0 | 90 - 95 | L | L | 3 – 6 days |
| Rhubard | *Rheum rhaponticum* | 0 | 95 - 100 | VL | L | 2 – 4 weeks |
| Rutabaga | *B. napus car. Napobrassica* | 0 | 98 - 100 | VL | L | 4 – 6 months |
| Sage | *Salvia officinallis* | 0 | 90 - 95 | | | 2 – 3 weeks |
| Salsify; Vegetable oyster | *Trapopogon porrifolius* | 0 | 95 - 98 | VL | L | 2 – 4 months |
| Sapodilla chicosapote | *Achras sapota* | 15 - 20 | 85 - 90 | H | H | 2 weeks |
| Seville; sour orange | *Citrus sinensis* | 10 | 85 - 90 | L | M | 12 weeks |
| Shallots bulbs | *Allium cepa var. ascalonicum* | 0 – 2.5 | 65 - 70 | L | L | |
| Snapbean; wax; green | *Phaseolus vulgaris* | 4 - 7 | 95 | L | M | 7 – 10 days |
| Snow peas | *Pisum sativum* | 0 -1 | 90 - 95 | VL | M | 1 – 2 weeks |
| Soursop | *Annona muricata* | 13 | 85 - 90 | | | 1 – 2 weeks |
| Southern cowpeas | *Vigna sinensis = V. Unguiculata* | 4 –5 | 95 | | | 6 – 8 days |
| Spinach | *Spinacia oleracea* | 0 | 95 - 100 | VL | H | 10 – 14 days |
| Spondias, Mombin, Wi apple, Jobo Hogplum | *Spondias spp.* | 13 | 85 - 90 | | | 1 – 2 weeks |
| Sprouts from seeds | *Diferente genera* | 0 | 95 - 100 | | | 5 – 9 days |
| Squash winter (hard ring); pumpkin | *Cucurbita moschata; C. Maxima* | 12 - 15 | 50 - 70 | L | M | 2 –3 months |
| Squash, summer (soft rind); courgette | *Cucurbita pepo* | 7 - 10 | 95 | L | M | 1 – 2 weeks |
| Strawberry | *Fragaria spp.* | 0 | 90 - 95 | L | L | 7 – 10 days |
| Sugar apple; Custard apple | *Annona squamosa; Annona spp.* | 7 | 85 - 90 | H | H | 4 weeks |

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|---|---|---|---|---|---|---|
| Sweetpotato "yam" | *Ipomea batatas* | 13 -15 | 85 - 95 | VL | L | 4 – 7 months |
| Tamarillo, tree tomate | *Cyphomandra betacea* | 3 - 4 | 85 - 90 | L | M | 10 weeks |
| Tamarind | *Tamarindus indica* | 2 - 7 | 90 - 95 | VL | VL | 3 – 4 weeks |
| Tangelo, Mineola | *Citrus reticulata* | 7 - 10 | 85 - 95 | | | 2 – 4 weeks |
| Tangerine, mandarin | *Citrus reticulata* | 4 - 7 | 90 - 95 | VL | M | 2 – 4 weeks |
| Taro; cocoyam; eddoe; Dasheem | *Colocasia esculenta* | 7 - 10 | 85 - 90 | | | 4 months |
| Thyme | *Thymus vulgaris* | 0 | 90 - 95 | | | 2 – 3 weeks |
| Tomatillo; Husk tomato | *Physalis ixocarpa* | 7 -13 | 85 - 90 | VL | M | 3 weeks |
| Tomato, firm-ripe | *Lycopersicon esculentum* | 8 - 10 | - 0.5 | L | | |
| Tomato, mature - green | *Lycopersicon esculentum* | 10 - 13 | 90 - 95 | VL | H | 1 – 3 weeks |
| Turnip root | *Brassica campestries var. Rapifera* | 0 | 95 | VL | B | 4 – 5 months |
| Water Chesnuts | *Eleocharis dulcis* | 1 - 2 | 85 - 90 | | | 2 – 4 months |
| Watercress garden cress | *Lepidium sativum Nasturtium officunales* | 0 | 95 - 100 | VL | H | 2 – 3 weeks |
| Watermelon | *Citrullus vulgaris* | 10 - 15 | 90 | VL | H | 2 – 3 weeks |
| White sapote | *Casimiroa edulis* | 20 | 85 - 90 | | | 2 – 3 weeks |
| Winged lean | *Psophocarpus tetragonolobus* | 10 | 90 | | | 4 weeks |
| Yam | *Dioscorea spp.* | 15 | 70 - 80 | VL | L | 2 – 7 months |

Part of the information presented here are modified from: Kader, A.A. (Ed.). 2002. Postharvest technology of horticultural crops. 3rd Edition, University of California, Agric. Nat. Res., Publ. 3311.

Ethylene production: VL = Very Low (< 0.1 μL/Kg.hr), L = Low =.1-1.0 μL/Kg.hr), M = Moderate (1.0-10.0 μL/kg.hr), H = High (10.0-100 μL/kg.hr), VH = Very High (> 100 μL/Kg.hr).

Ethylene sensitivity: L = low sensitivity, M = medium sensitivity, H = high sensitivity.

# Sources of additional information

**Web sites:**

**Agricultural Internet Services:**

AgAccess Information Service / Ceres Online: http://www.ceresgroup.com
Information Services for Agriculture: http://www.aginfo.com/agsearch.html
Agri-Net trading: http://www.agri.net.com/
Intellicast Weather: http://www.intelicast.com/
Organic Farming and Produce Links: http://www.rain.org:80/-sals/my.html
Inverizon Ag-Links: http://www.inverizon.com
Allibert Contico Collapsible Containers and Pallets:
http://www.allibertcontico.com
Produce Net: http://www.producenet.com/

**Biotechnology Extension and Information:**

National Biological Impact Program: http://www.nbiap.vt.edu
Biotechnology Information Center: http://www.nal.usda.gov/bic/
Agricultural Biotechnology (BIO): http://www.bio.com
Information Systems for Biotechnology: http://gophisb.biochem.vt.edu/

**Commissions, Boards, Organizations:**

California Tomato Commission: http://www.tomato.org
National Watermelon Production Board: http://www.watermelon.org
National Mushroom Council: http://www.mushroomcouncil.com

**Consumer Direct Marketing:**

WholeFoods, Inc.: http://www.wholefoods.com/wf.infoguides.html
FloraSource: http://www.flora-source.com
Frieda's, Inc: http://www.friedas.com
Veggie Express: http://www.veggieexpres.com/
The Green Grocer: http://thefoodstores.ocm/tgg/html/
Consumer Information Produce Oasis: http://www.produce.oasis.com
Cut Flower Wholesale, Inc.: http://www.armellini.com/where.html#wholesalers
PeaPod Direct Produce: http://www.peapod.com/
Calavo: http://calavo.com
FoodNet On-Line: http://www.foodnet.com/

**Diagnostic Services & Residue Testing:**

Primus Laboratories: http://www.primuslabs.com

**Ethylene and Ripening:**

Catalytic Generators, Inc.: http://catalytic.symweb.com
Dade Services Corporation: http://www.dadesvc.com/main1.htm
Ethylene Control, Inc.: http://www.ethylenecontrol.com/

**Food Safety:**
Institute of Food Science and Engineering:
http://ifse.tamu.edu/ifse/foodsafety.html
Environmental Working Group-Food Pesticides: http://www.ewg.org/
National Food Safety Database: http://www.foodsafety.org

**Government Agencies:**
United State Department of Agriculture: http://www.usda.gov
Food and Drug Administration: http://www.fda.org
Environmental Protection Agency: http://www.cpa.gov
The National Agricultural Library: http://www.nalusda.gov/
Quality Standards-Fresh Fruit and Vegetables:
http://www.ams.usda.gov/standards/stanfrfv.htm
Food Safety Inspection Service: http://www.usda.gov/agency/fsis/
Agricultural Marketing Service Home Page: http://www.usda.gov/ams
Marketing and Transportation Analysis: http://www.usda.gov/ams/tmd.htm
Agricultural Export Programs: http://www.atinet.org/aep

**Instrument Design, Fabrication, and Consulting:**
Postharvest Research: http://www.davis.com/PHR/
Nitec, Inc: http://www.nitecinc.com
Special Commodities Services: http://members.aol.com/SCSFFVI/Index.html
Intermediate Technology Development Group: htpp://www.one,world.org.itdg

**Marketing information:**
Global Agribuisness Information Network: http://www.milcom.com/fintrac/
University of Florida Market Information System:
http://gnv.ifas.ufl.edu/marketing/market.html
U.S. Apple & Pear Marketing Board: http://www.fruit-usa.com
Fresh Solutions: http://www.mindsprine.com/-fresh/
DTN Produce Grower: http://www.dtn.com/ag/produce
Information Services For Agriculture: http://www.aginfo.com/agserach.html
Produce Marketing Association: http://www.pma.com
Food Marketing Association: http://www.fmi.org
The Packer: http://www.thepacker.com
Today's Market Prices: http://www.todaymarket.com
National Restaurant Association: http://www.restaurant.org

**Packaging and Containers:**
Packaging Intelligence Network: http://www.pin.santry.com/
San Jose State University Packaging Program: http://www.sisu.edu/depts/packtech/
WeighPack: http://www.weighpack.com
Packaging Strategies: http://www.packstrat.com
FabriForm Inc.: http://arweb.com/crpages/export/fabri/fabri.htm
Mobile Forced Air Cooling Services, Inc.: http://www.coolforce.com

**Production and Handling:**
Produce Reporter Company/Blue Book Services: http://www.bluebookprco.com/

**Research and Extension Information:**
Washington State University, Tree Fruit Research & Extension Center: http://postharvest.tfrec.wsu.edu/ North Carolina State University, Postharvest Commodity Series, Department of Biological and Agricultural Engineering:Http://www.bae.nscu.edu/programs/extension/publicat/postharv/
North Carolina State University, Horticulture Information Leaflets, Postharvest Handling of Horticultural Crops: http://www.ces.ncsu.edu/dept/hort/hil/post-index.html
Food and Agriculture Organization of the United Nations. Provides world wide systems information on postharvest of grains and perishables. Also a communication platform for postharvest experts:http://www.fao.org/inpho/
International Association of Refrigerated Warehouses:http://www.iarw.org
Produce Marketing Association:http://www.pma.com
United States Department of Agriculture:http://www.usda.gov
U.C. Davis Postharvest Technology:http://postharvest.ucdavis.edu/
U.C. Integrated Pest Management: http://www.ipm.ucdavis.edu
Center for Postharvest and Refrigeration Research: http://agtv-pc11.massey.ac.nz/centres/cprr/centre.htm
USDA-ARS Tree Fruit Research Laboratory: http://www.tfrl.ars.usda.gov/
International Food Information Center: http://ificinfo.health.org
U.C. Vegetable Research & Information Center: http://vrichome.ucdavis.edu
U.C. Fruit & Nut Research and Information Center: http://pom44.ucdavis.edu
U.C. Food Science and Technology: http://www-foodsci.ucdavis.edu
Department of Environmental Horticulture, UC Davis: http://envhort.ucdavis.edu/
Texas A&M Horticulture: http://aggie-horticulture.tamu.edu/
North Carolina State University Postharvest Extension Programs: http://www.bae.ncsu.edu/bae/programs/extension/
Herbs Home Page: http://hortweb.cas.psu.edu/vegcrops/herbs.html
5-A-Day: http://dcpc.nci.nih.gov/5aday/

**Sanitation:**
Water Quality Association: http://www.wqa.org
Chlorine Handling: http://c3.org

**Shippers, Suppliers, Brokers:**
Mission Produce Co.: http://www.missionero.com
The Nunes Co.: http://www.foxy.com
J. Sainsburry: http://www.j.sainsbury.co.uk/
Dole: http://www.dole5aday.com
Chiquita Online: http://www.chiquita.com
Plantation Vidalia Onions: http://www.plantationsweets.com

Christopher Ranch Garlic: http://www.garlic.com
Inspection Services: http://www.digispect.com/
Controlled Temperatures Shipping Products:
http://www.donovan-ent.com/insulp.htlm
Produce Misting Solutions: http://www.mindsprine.com/-kes/homepage.htm
Monterey Mushrooms Inc.: http://www.montmush.com/
Nature Ripe Berry Growers: http://www.naturipe.com

**Temperature Recording:**
Cox Recorders: http://www.cx-en.com/cox.htm
Sensitech: http://www.temptale.com

**Transportation:**
American President Lines; http://www.apl.com
Armellini Expressline: http://www.armellini.com
OOCL Inc.: http://www.occl.com
Maritime Global Net: http://www.mglobal.com
Roadway Online: http://www.roadway.com
Matson Navigation Co.: http://www.matson.com/
Agri-Net Transportation Finder: http://www.agri-net.com/
The Transport Web: http://www.transportweb.com/
Sealink Services: http://www.sealink.com
Farmington Fresh Air Transport: http://www.mccarty.com/affil/farmfresh
Sealand Services Inc.: http://www.sealand.com/
C.H. Robinson Co.: http://www.chrobinson.com/
Australia – New Zealand Direct Line: http://www.anzdl.com