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Ministry of Agriculture

GUIDE

Preventing post-harvest losses in the apple supply chain in Lebanon

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Cover picture: Golden and starking apples
Source: Ahmad el Saegh

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1. Acknowledgements

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2. Introduction:

It is estimated that one third of all food is lost or wasted globally every year. Within this total, approximately 20-40 percent of all fruits and vegetables in developing countries, and 10-15 percent in developed countries are lost during post-harvest stages of the value chain, due to lack of technology and poor food handling practices (Gustavsson et al, 2011).

Food loss and food waste refer to the decrease of food in subsequent stages of the food supply chain intended for human consumption. Food is lost or wasted throughout the supply chain, from initial production down to final household consumption.

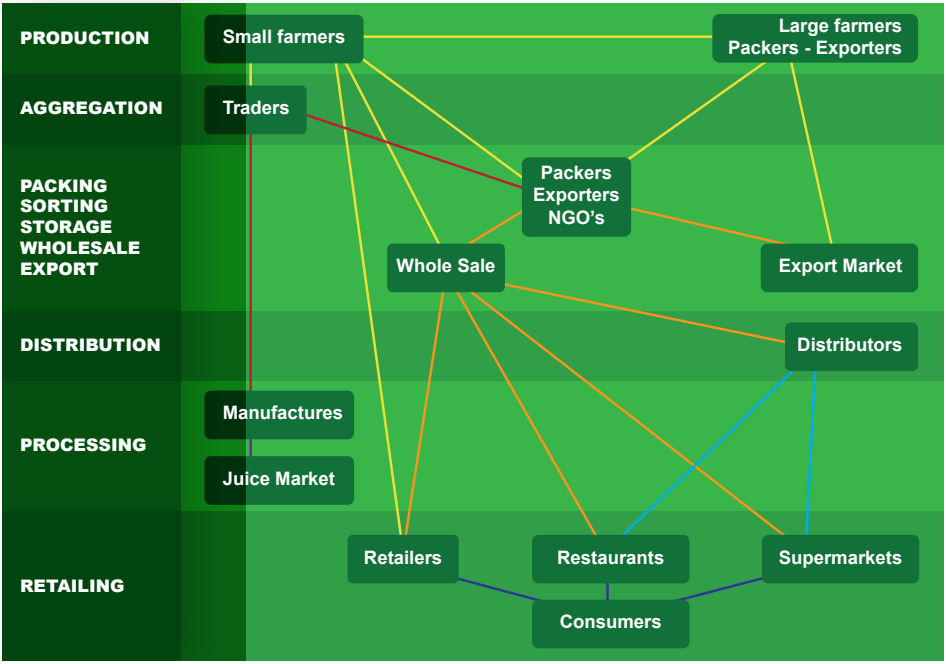
The decrease may be accidental or intentional, but ultimately leads to less food available for all. Food that gets spilled or spoilt before it reaches its final product or retail stage is called food loss. Food that is fit for human consumption, but is not consumed because it is or left to spoil or discarded by retailers or consumers is called food waste.

Food loss reduction in agricultural value chains is an important part of the work that FAO is doing. Under the supervision of the FAO Regional Representative for the Near East and North Africa and the Lebanese Ministry of Agriculture, this manual is developed in the context of a Technical Cooperation Project to build capacity for better post-harvest handling of fruits in Lebanon. A screening study was conducted on the fruits supply chains in Lebanon, and it was observed that the apple fruit subsector is suffering from major losses along the value chain, from harvest until reaching the market. A separate project being conducted in parallel is studying the apple fruit subsector, where this manual has benefited from the observations and findings of the study team.

Fruit losses occur due to decay, mechanical damage, physiological disorders, and infestation of several fruit flies during harvest, storage, and transport stages. In Lebanon, observations in the field have shown that sometimes in one crate almost all apples are lost due to mechanical damages (Chahine and Tawk, 2016). Losses occur on several levels starting in the field due to poor farming practices, then continue at harvesting and post-harvesting until the final product reaches the consumer. Poor practices are negatively affecting the reputation of the Lebanese apples both at local and export markets, rendering Lebanese apples unmarketable.

In the screening report, the map of the Lebanese apple supply chain was developed; the baseline information highlighting the causes of apple post-harvest losses was identified, and the critical loss points in the apple supply chain were determined. Afterwards, a training needs assessment was conducted by interviewing stakeholders in three different locations: Mount Lebanon, Bekaa and Akkar. In the assessment, questionnaires were completed with 15 farmers, as well as 4 traders, and 4 cold storage managers from the selected areas. In addition to that, two interviews were conducted, one with a wholesale manager, and another with a retail manager.

Picture 1: Value chain map for the apple subsector in Lebanon



Source: Adapted from Montigaud et al., 2004

Results from the training needs assessment were analyzed to determine key capacity building needs, design a training curriculum, and to conduct a workshop on the prevention of apple losses. The workshop included presentations, field visits, and on-hand demonstrations on reducing apple losses.

3. Post-harvest technology in apples

Post-harvest technology in apples refers to the whole range of handling practices from field (harvesting) to market, in order to maintain the quality and safety of fresh apples during distribution. The main objective of applying post-harvest technologies to harvested apples are:

3.1. Maintain quality of apples:

The quality of fruits is measured by appearance, texture, flavor, taste, and nutritive value. Farmers generally try to harvest the fruit while still immature in order to reduce their losses, which occur mainly during the harvesting, packing and transport stages. Immature fruits have not reached the maturity level necessary for good eating quality (sugars, taste and color development), where eventually they are rejected as consumers do not favor immature fruits. This leads to rejection at retail level, causing sale reduction, and further, fruits are thrown out due to inadequacy.

3.1.1. Quality attributes for apples:

Apple farmers need to learn about the quality attributes for apples in order to produce high quality apples. Handlers (traders, cold storage managers, and packers) should also learn about these attributes in order to maintain the quality after harvest, during storage, and in delivery. Losses in apples mainly occur due to production of fruits with low quality attributes. Therefore, understanding the proper quality attributes for apples will help decrease fruit losses, and also have higher financial returns to all apple supply chain stakeholders, as the end product will be sold at a premium price.

Table 1: General quality attributes to all varieties:

Quality Attributes	Property
Visual aspects	Color Shape Size
Organoleptic qualities	Taste Flavor Texture Aroma
Texture	Firm & Crispy
Free from physiological problems	Freezing injury, Heat injury
Free from defects	Bruising Decay Stem or blossom-end cracks, bitter pit, scald, internal browning,or shrivel

Source: Kader, 2011

3.2. Ensure food safety

Consumers are now worried about food-borne diseases. It is the responsibity of growers and post-harvest handlers to use handling practices that will ensure food safety to protect apples from contamination. The typical causes and sources of food safety problems during post-harvest handling fall into the following three major categories:

• Physical Hazards: During packaging there are possibilities that hazardous items such as staples, nails, screws, pieces of glass, or wood fall into apple crates.

• Chemical Hazards: Pesticides, fungicides, herbicides, rodenticides, machine lubricants from forklifts or packing line equipment, andcompounds used to clean and sanitize equipment are considered as chemical hazards if came in contact with apples.

• Human Pathogens: Soil and feces can carry bacteria or fungus that can contaminate apples (Kitinoja and Kader, 2002).

3.3. Reduce post-harvest losses

Post-harvest losses are the losses that occur between harvest and consumption stages. These losses could be physical, cosmetic, or nutritional, and can translate into economic loss for the value chain actor.

• Physical: These losses can occur due to infestation from insects, pests, mites, rodents, birds, or from handling. This deterioration makes apples unfit for human consumption thus become rejected, which contributes to food loss.

• Cosmetic: Cosmetic losses have defects such as blemishes, bruises, misshaped fruits, and change in the desired color. Fruits with cosmetic defects may still be consumed, or can be discarded and contribute to food loss or waste.

• Nutritional: Nutritional losses in apples occur due to chemical changes in carbohydrates and vitamins and pigments.

• Economic: Reduction in value or loss of economic value due to qualitative losses leading to apples being sold for a lower price, or a total loss of value if the apple is discarded.

Module 1: post-harvest losses, their causes and solutions in the apple supply chain:

Farmers, dealers, wholesale managers, retail managers, packing house, and cold storage operators, lack knowledge about proper post-harvest technology. These wrong practices occur at pre-harvest (cultural practices in the field), harvest, and post-harvest stages, which contribute to significant losses in the Lebanese apple supply chain.

1. Post-harvest losses resulting from pre-harvest practices and their solutions:

Poor cultural practices during production, such as improper pruning, thinning, fertilization and disease control, can reduce the quality and increase post-harvest losses. Common pre-harvest practices that lead to post-harvest losses and their solutions are summarized below, along with their solutions.

Type of loss	Solutions or Proper Pre-harvest Practices
1- Poor color for red varieties or delay in change from green to yellow in Golden Delicious variety. **Causes of loss** • Fertigation with high levels of nitrogen. • Improper pruning.	Proper pruning should be done in order to provide balance between vegetative and fruit growth. In addition to that, removal of all weak and unproductive branches thus ensuring the formulation of a well-structured tree. This will allow light and air to reach both the inner parts of the tree and the fruits leading to an improvement in color. The ideal time for pruning apples is in February, while spring or summer pruning can be done only for diseased branches.
2- Small sized fruits **Causes of loss** • Fertigation with low levels of potassium. • Irrigation cutoff. • Improper thinning of fruits.	Potential fruit size reduces when irrigation is not sufficient. Irrigation for apples should begin in June, and depends on tree age (canopy), soil type, and on summer days (evapotranspiration mm / day / month). In general, the overall amount of water needed per season per dunum is around 600 m3. Thinning is necessary during the season where there's a heavy fruit set. The goal is to leave plenty of room for each apple to mature. For examples, if you expect mature apples to be 7.5 cm in diameter, 15 cm should be left between each apple after thinning. Moreover, if unsure of the size of the apples on your tree at their peak, then thin to a distance of 15 to 20 cm apart on the branch. When to perform thinning? The thinning period differs among apple varieties, but in general thinning should start when the diameter of the fruit reaches 1 cm, usually mid-June. Even as apples approach half their preferred size in the middle of summer, you can still thin the crop.
3- Apple codling moth: *Cydia pomonella* **Causes of loss** • Brown secretions on the fruit mainly at the point where the larva enters or where two apples touch.	Perform thinning to the fruit, and remove the infected fruits away from the orchard. Larvae must be prevented from entering the fruit. In order to do so, spray for larvae contact insecticides like chlorpyrifos. The first spraying of the season targets the first hatching eggs for the first generation. Repeat the spraying after 6 weeks for second and third generations. It is worth noting that once the eggs hatch and larvae enter the fruit, control measures are no longer effective.

	Pheromone traps placed in the orchard monitor the appearance of adult insects, however they are not an effective control practice as they only capture males, and a reduction in males will not reduce female mating due to their polygamous behavior. Source: Alston, 2003
4- Apple Leafroller: *Archips argyrospila* **Causes of loss** • Larvae's damage results in shallow cavities in the fruit. Damaged fruits that remain on the tree develop deep bronze-colored scars with roughened, netlike surfaces.	Apple leaf roller is usually controlled by a dormant oil spray to cover egg masses. Check results by sampling for leaf rollers at green tips, if larvae are found after one week, it is necessary to spray insecticides like Coragen® or Belt SC or Bacillus thuringiensis or Spinosad before pink bud to prevent damage. Infestations are often confined to small, localized areas of the orchard, thus can be spot treated. Source: Wunderlich et al., 2016
5- Misshaped fruits. **Causes of loss** • Uneven irrigation.	Farmers should receive assistance from extension engineers in determining water requirements for their apple trees.
6- Bitter pit* **Causes of loss** • Incorrect fertilization: High levels of nitrogen fertilization and low levels of calcium. • Irrigation cutoff. • Red Delicious, Fuji and Granny Smith are susceptible varieties.	Best controlled by proper fertilization; therefore, do not over fertilize with nitrogen. Calcium deficiency causes major losses in apples, as it has a big influence on the quality of the fruit, where it is required to strengthen the cell walls of the fruit. Calcium is relatively immobile in soil and plants. It is often the case that even through calcium levels in Lebanese soil are high, trees may be unable to extract sufficient quantities of calcium from the soil, especially when winter rains are below average. For that reason, corrective measures in foliar sprays of calcium are necessary. Calcium sprays should be applied in the early summer every 7 to 10 days until harvest. Spraying rates for calcium Oxide are suggested at 350 cc / 200 L. Moreover, calcium nitrate is not recommended for red apples, as it can lead to poor fruit color. Several suitable foliar calcium spray formulations are also available in Lebanon, where farmers should check for the availability of calcium foliar fertilizers in the Lebanese markets, other than calcium nitrate.

***Bitter pit on apples:**
Symptoms include sunken brown, dark and dry pithy spots or pits on the skin, especially near or below the calyx end. Premature and /or large fruit from young, vigorous trees are most susceptible. Bitter pit on apples usually develop while still on the tree, or during the first 4 – 6 weeks of storage.

	Furthermore, spraying rates should be written on the container of the product. It is important to know that since calcium absorbed by the leaves will not move to the fruit, calcium sprays must contact the fruit surface.
7- Cork spot on apples **Causes of loss** • Boron deficiency	Reduce losses by including boron sprays while spraying calcium. Boron should be applied before and after blooming. Spraying rates are borax at 100 grams / 200 L.
8- Apple Scab: *Venturia inaequalis* **Causes of loss** • Susceptible Varieties: Red Delicious susceptible varieties. • High humidity areas accompanied by moderate temperature.	Scab infects both the apple leaves and the fruits. Once the fruit is infected, brown to black spots grow on the outer skin of the fruit. When the fruit is stored, the spots crack causing the fruit to deform and become unmarketable. The infection may start in the period between blooming till the fruit becomes 1.5 cm in diameter and the main leaves grow. For prevention, spray micronized sulfur. As for a curative spray, use hexaconazole, fenarimol, myclobutanil and/ or flusilazole.
9- Sooty mold **Causes of loss** • Green rosy apple aphid secretes honey dew and the sooty mold grows on it thus decreasing the quality of the apple.	Lack of pest management. Use resistant rootstocks (check Annex 2 about apples rootstocks). Pre-harvest disease management in the field is an important component of integrated pest management strategy (check Annex 3 about Pest and disease management).
10- Soft fruit & reduced firmness **Causes of loss** • Incorrect fertilization with high levels of nitrogen and low calcium. • Over Irrigation. • Harvesting apples at improper maturity stage.	Fertigation is irrigation while adding soluble fertilizers through drip irrigation systems. Fertigation gives quicker uptake of nutrients than surface broadcast fertilizers, because the applied materials (Nitrogen, phosphorous, potassium, magnesium, boron, and zinc…) move rapidly to the root zone when combined with water. Farmers should consult with extension engineers about quantities of soluble fertilizers for their orchards.

11- Water Core* **Causes of loss** • Low calcium levels. • Fruits subjected to low temperatures in cold regions at high altitudes.	Spray calcium every 7 to 10 days until harvesting. Avoid planting susceptible varieties like Fuji in cold areas.
12- Internal Browning or Brown Heart **Causes of loss** • High nitrogen fertilization to trees with light crop load. • Fruits subjected to low temperature in cold regions at high altitudes.	Reduce nitrogen fertilization when the crop load is minimal. Spray calcium every 7 to 10 days until harvesting.
13- Rot including Core rot and Mucor rot **Causes of loss** • Lack of sanitation in the field and workers. • Disease spores are usually present in the orchard. Once apple fruits are infected with these spores the incidence of rot damage increases.	Reduce conductive environments for pathogen infection and disease development, and minimize the amount of the pathogen that may infect or contaminate the crop before harvest. Rots on stored apples can be significantly reduced by good pre-harvest /sanitation processes at all stages in fruit production and handling including the following: • Prune apple trees to form orchards with good air movement, and eliminate low branches, which can lead to contact between the fruit and weeds or soil • Weeds should be managed to ensure good airflow around trees, and to reduce the development of moist humid conditions that promote the development of apple diseases • Weeds should not be allowed to grow under trees as they are reservoirs for fungal spores, which can be released when the grass is disturbed especially in humid conditions • Remove diseased wood and mummified fruits during winter and summer pruning. • Maintaining good pest control programs to avoid fruit damage

***Water Core:**

Appears as glassiness of fruit flesh late in the growing season. It is usually associated with advanced maturity, and low calcium levels. Red Delicious, Fuji and Granny Smith are prone to this disorder. Water core does not develop in fruits after harvest. Water-cored fruit is sweet resulting from the accumulation of sorbitol (sugar alcohol). It is also usually large and attractive at harvest, but such fruit will deteriorate rapidly in storage.

Picture 2: Apple fruit infected with apple codling moth, *Cydia pomonella.*

Source: Cox et al., 2003

Picture 3: Apple fruit infected with apple leaf roller, *Archips argyrospila.*

Source: Beers, 1993

Picture 4: Bitter Pit.

Source: Edwards, 1996a

Picture 5: Apple scab.

Source: Maňas, 1999

Picture 6: Water core on Granny Smith apples.

Source: Edwards, 1996b

2. Post-harvest losses resulting from harvesting practices and their solutions:

Problem	Solutions or Proper Harvesting Practices
1- Delay in ripening and storage disorders **Caused by** • Harvesting at improper maturity.	Harvesting at Proper Maturity Stage: The difference between an immature and over-mature apple fruit is only 7 to 14 days depending on the variety, location of orchard, weather, and cultural practices (pruning, fertilizers applications etc). The proper maturity stage can be identified by using maturity indices for apples, such as: • Starch Iodine (SI) Test for Maturity • Soluble Solids Content (SSC) • Fruit Firmness Test • Number of days from full bloom • Seed color • Skin color
2- Mechanical injuries (external bruises and wounds). **Caused by** • Picking the apples while still humid. • Harvesting during the hot hours of the day. • Unexperienced pickers. • Apples that fall and hit lower apples. • Apples hitting the ground soil while harvesting. • Pickers' fingers with long nails. • Pickers' jewelry. • Climbing trees.	Apples on the tree should be allowed to dry before harvesting. Avoid picking when apples are still humid or during hot hours of the day because apples will bruise easily. Pickers should use both hands when harvesting by grasping the apple fruit firmly but gently and pulling it upwards. Picking sacks should have shoulder straps, thus allowing the picker to use both hands (picture 7). Picking should be done from the outside to the inside of the tree canopy and from lower to upper parts. This is done to avoid apples from upper branches falling and hitting the apples on lower branches, resulting in both falling on the ground while harvesting. Pickers should not press the apple fruit with their fingers or nails; in addition to that, they should trim their nails and wear gloves to prevent damages caused by the pickers' nails. Pickers should remove jewelry such as rings and bracelets. Pickers should be provided with lightweight ladders (aluminum) if necessary, to help them reach high fruits.

• Throwing harvested apples into rigid plastic buckets without using liners (shock absorbers). • Throwing, dropping, pouring or dumping (roughly) the apples from the buckets into the plastic crates.	Pickers should place the fruits into padded bags or sacks gently. These sacks should have soft bases and sides to prevent damage to fruits. Padded bags or sacks are not used in Lebanon, however, farmers can install soft pads to the sides and the base of the picking buckets to absorb the impacts on the apples. Once the bags or padded buckets are full, the workers should gently empty the fruits from the bags/padded buckets into the plastic field crates.
3- Compressed fruits. **Caused by** • Over packing of field crates.	Pickers should not overload plastic crates.
4- Crushed and destroyed apples. **Caused by** • Stacking crates of different sizes over each other, will lead to the smaller crate smashing the apples in the bigger crates. • Stacking apples crates too high while using weak boxes will break the lower crates.	Crates should be uniform, in good condition, and strong enough to withstand stacking (not broken), in order to be piled properly and easily.
5- Sunken and concave bruises. **Caused by** • Rough driving on unpaved roads. • Over-loading vehicles.	Unpaved roads require slow driving to avoid vibration injury. Reduce the air pressure in the wheels of the pickup.
6- Physiological Breakdown: Sun burn damage. **Caused by** • Heat Injury: Symptoms include bleaching, surface burning, uneven ripening, softening, and desiccation.	Put the filled crates under shade. Do not expose the apples to direct sunlight after harvesting. The shaded area can be temporary constructed prior to the harvest season and removed immediately once finished, or moved from orchard to orchard as harvesting continues. Do not expose the apples to excessively high temperatures.

7- Soft Scald **Caused by** • Over mature fruit is more susceptible to soft scald especially when stored at low temperatures.	Harvesting at proper Maturity Stage.
8- Storage Scald **Caused by** • Early season or low maturity fruit is more susceptible to storage scald.	Harvesting at proper Maturity Stage.
9- Botrytis (Gray mold) & *Penicillium expansum* (Blue mold) **Caused by** • Rough handling causing scratches and wounds, these injuries become the perfect place for molds to grow. • Washing/drenching of fruit spreads spores from bins to fruit wounds and fruit stems where they can initiate rots and molds.	Avoid fruit injuries. Cool the fruit quickly. Sanitize the water with chlorine. If fruits will be washed/drenched before storage, the fruit drenching water must be clean (potable), where it should contain a food safe sanitizing agent to kill any spores introduced into the water. The water should be changed regularly and frequent checks should be carried out to ensure that the sanitizer in the water remains effective.
10- Water Core **Caused by** • Harvesting over mature apples. Water cored fruit deteriorate rapidly in storage.	Harvesting at the proper maturity level.
11- Internal Browning **Caused by** • Over mature apples.	Harvesting at the proper maturity level.

12- Rots

Caused by

• Picking apples without the stem or peduncle will increase the incidence of rots and decays.
• Harvesting in dirty buckets.
• Collecting in dirty crates.
• Farmers in Lebanon collect the harvested apples in plastic crates and put these crates on the soil under the tree before sending them to cold storage. This leads to contamination of the crates from below, where the pathogens will be transferred to other apples when stacked over each other.
• Apples that fall accidentally on the ground while harvesting will become bruised and contaminated.

Apples without peduncle should not be sent to storage; instead they can be packed to direct consumption.

Maintain Hygiene in the field by establishing toilets and washing facilities (with liquid soap and paper towels) in the field. It is important to inform workers on the need for good personal hygiene.

Clean hands, short fingernails, and clean gloves are required to ensure that rots are not spread to the fruit.

Make sure all dried, mummified, and rotten fruits are removed from used crates before cleaning them.

Clean the plastic buckets or bins before harvesting with bleaching agent (2 percent Clorox solution).

Use clean plastic buckets before and during harvesting.

The pads in the buckets must be clean to prevent the transfer of disease/fungal spores to the apples' surface, which will lead to infections and rotting at storage.

Farmers should separate field crates from storage crates. If storage crates are placed on the soil then stacked over each other in the cold storage, the apples in the lower crates will be contaminated, as contaminated soil will fall from the base of upper crate to the apple fruit of the lower crate.

Never send bruised fruits that contacted the soil to storage, as they will rot later during storage.

Design and implement an orchard fungicide spray program, targeted against specific rot risks.

Picture 7: Picking bags or sacks used for harvesting apples.

Source: Banse, 2014

Picture 8: Bruises from over filled crates.

Source: Nakad. 2005

Picture 9: Ununiformed crates causing damage to apples.

Picture 10: Crates.

Source: Nakad. 2005

Picture 11: Soft Scald.

Source: Cline, 2009

Source: Clements, 2007

Picture 12: Storage Scald.

Source: Edwards, 1996b

Picture 13: Blue Mold & Gray Mold.

Source: OMAFRA, 2009

3. Post-harvest losses resulting from post-harvest practices and their solutions:

Problem	Solutions or Proper Harvesting Practices
1- Rots **Caused by** • Inadequate chlorine in washing water before storage. • Dirty storage crates. • Lack of proper sorting.	The crates must be clean and well ventilated. Clean the plastic buckets or bins with a bleaching agent (2 percent Clorox) before storing. All bruised, injured and wounded apples should be sorted before storage. These fruits should never enter the storage because they will rot quickly causing the good apples to rot as well.
2- Decay **Caused by** • Long delays without cooling before and after packing. • Improper sorting. • Accidently wetting the apples in the crates while pouring water on the ground of the storage to increase relative humidity (RH). • Misuse of controlled atmosphere (CA).	Full crates should be transported to the market or cold storage on the same day of harvesting. If sorting was done at the packing station, bruised and injured apples, as well as apples without peduncles should be culled away. Apple fruits should be pre-cooled before cold storage. Avoid wetting the apples while in storage. Regular checking for O2 and CO2 concentrations in the CA to avoid very low O2 and high CO2 concentration, which might increase the incidence of decay. The use of CA is highly technical, for example different varieties of apples react differently to differing levels of oxygen/carbon dioxide concentrations. Cold storage managers who want to consider CA should seek technical advice from specialist.
3- Bitter pit **Caused by** • Misuse of post-harvest treatments. • Developed during the 4 to 6 weeks of storage.	CA storage can reduce the symptoms of bitter pit. Dipping the apple fruit in calcium chloride at 1000 g/ 200 L before storage. **Source:** (Department of Agriculture, Queensland Government site, 2014)
4- Physiological breakdown **Caused by** • Freezing injury, resulting in immediate collapse of their tissues.	Do not store apples below their freezing temperatures which is -2°C

5- Cosmetic loss in the fruits' appearance (shriveling) and loss in salable weight, where the fruit will become soft and lose its crispiness and juiciness. **Caused by** • Injured and over mature apples are subjected to high water loss • Lack of efforts to maintain high RH in the cold storage.	Proper sorting while packaging. Water loss can be reduced by decreasing temperature in the cold storage while maintaining high RH and good air circulation. Installing humidifiers will add all moisture to air to increase humidity. Humidifiers are connected to a hygrometer and sensors, which will turn on when the sensor reads RH lower than 85 percent. Wet the floor of the cold storage rooms regularly, specifically under the pallets.
6- Storage Scald **Caused by** • Granny Smith apples are very susceptible to storage scald especially when grown in hot dry climates. However, Gala and Fuji appear to be slightly susceptible to scald.	Do not plant Granny Smith apples at low land where summer days can be hot and dry. Drench apples with Diphenylamine (DPA) before storage, especially for storage beyond 3 months. CA storage can reduce scald incidence and severity. Reduce ethylene levels in storage, as it also reduces scald development. The lower the oxygen concentration used, the better the scald control (make sure fruit tolerance to low oxygen is first determined). Reduce nitrogen fertilization when the crop load is minimal.
7- Internal browning or brown heart **Caused by** • Extended storage of over-mature fruit • Delaying cold storage, • It is worsened by high CO2 concentrations in CA storage. • Light crop load on the trees. • Production in colder regions or seasons, and higher altitude areas. • Fuji apples are susceptible to CO2 injury during the first weeks of CA storage after harvest.	Use of calcium sprays. Limit the storage period of late harvested or over mature fruits. Post-harvest treatment with diphenylamine (DPA) effectively prevents the development of CO2 injury in Fuji apples. Minimum development of brown-heart occurs in Fuji apples in the following conditions: • When they are stored in CA delayed for 4 or 6 weeks after harvest. • When they are stored in CA with CO2 accumulation delayed for 1 month after harvest. • When they are stored in 1-MCP-treated fruit stored in CA with low (0.05 percent) CO2.

8- Irregular ripening of fruits

Caused by

• Lack of ventilation in the cold storage.

Install automatic ventilation windows in the cold storage rooms.

Manual ventilation by opening the door of the cold storage.

Make sure to use proper crates with vents, as sometimes due to manufacturing defects, crates come without vents.

9- Off flavors and odors

Caused by

• Lack of ventilation in the cold storage.

• Unintentional reduction in O2 and increase in CO2 concentrations can cause anaerobic fermentation leading to alcohol formation that causes off flavors and tissue breakdown in the CA storage.

The cold store manager needs to always monitor the concentrations of O2 and CO2 in the cold storage.

Cold store managers should not mix apple varieties that have different tolerance levels to O2 and CO2 while using CA in the same cold storage room.

Install automatic ventilation windows in the cold storage rooms.

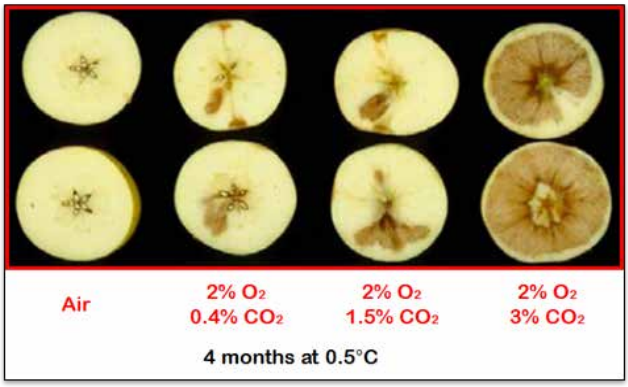
Manual ventilation by opening the door of the cold storage.

Make sure to use proper crates with vents, as sometimes due to manufacturing defects, crates come without vents.

Picture 14: Ventilated crates Vs. Non ventilated crates.

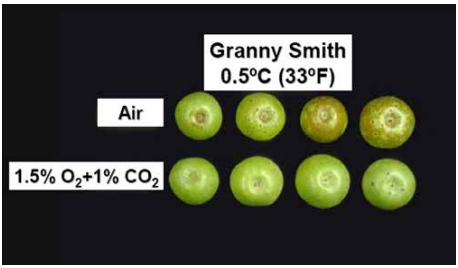
Source: Nakad. 2005

Picture 15: Controlled atmosphere harmful effect. Internal browning.



Source: Edwards, 1996a

Picture 16: CA's positive effect. Reduce bitter pit in Granny Smith apples stored at 0.5°C.



Source: Edwards, 1996b

Module 2: Maturity indices for apples

Maturity indices for apples are used to determine when apple fruits have reached maturity and have started to ripen. They also allow farmers to decide when to harvest their apples.
There are several indicators of maturity used, which include:

1. Starch Iodine (SI) test for maturity

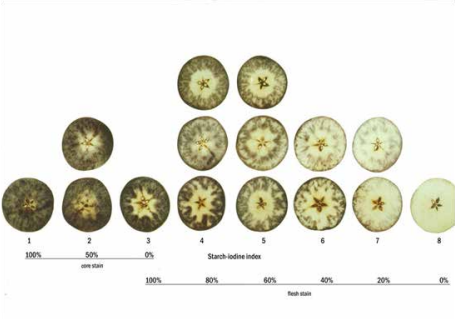
SI is a reliable method for determining maturity for most apple varieties, and is considered the easiest indicator of apple maturity. As an apple ripens the starch in the fruit turns to sugar. This test measures the level of conversion of starch to sugar. An example of Starch Iodine Chart for Granny Smith is shown in Picture 18.

As a rule, fruits with an SI reading of 3-4, when compared to a SI chart, are suitable for long-term storage. Apples with a reading of 4-6 are best for short term storage, where apples reading 6 or more should be placed in regular cold storage or sent to markets immediately. The equipment used for SI testing consists of a one liter hand-operated spray bottle filled with SI solution, a pocket knife, and a Starch Index chart.

The iodine should be prepared freshly each harvest season, and stored in a dark container during the season, as it is sensitive to light. A farmer can easily make the iodine solution as follows:

1. Dissolve 9 grams of potassium iodide in about 30ml of warm water.
2. Gently stir the solution until the potassium iodide is properly dissolved.
3. Add 2 grams of iodine crystals and shake the mixture until the crystals are thoroughly dissolved.
4. Dilute this mixture with water to make 1 Liter of test solution, making sure to mix well as iodine is a very poisonous chemical and should be labeled “POISON” with the name IODINE SOLUTION. This mixture must be kept away from children.
5. It is very important to begin sampling and testing the fruit two weeks before the expected harvest, to obtain a baseline level for fruit maturity.
6. The procedure is simple: pick a sample of apples in an advanced stage, that appear ready to harvest, based on their size, color, number of days after full bloom, and taste/sweetness.
7. Cut the fruits horizontally in half at the center.
8. Spray the halved fruit with the SI solution, making sure the surface is thoroughly wet. After approximately one minute, the areas with starch will react with the iodine and turn blue-black and the sugar areas will stay white.
9. Wait for 1 – 1.5 minutes and make a reading by comparing the starch sugar ratios with SI charts. Generally in an orchard there is an increase of one starch unit every 5 days, although this can be accelerated in hot weather.

Picture 17: Starch staining pattern for Red Delicious: dark areas indicate starch, light areas indicate sugars.



Source: Edwards, 1999

Table 2: Suggested starch index levels by variety.

Variety	Starch Index*	
	Mature	Over mature
Fuji	3	7
Gala	3	6
Golden Delicious	3	6.5
Red Delicious	2.5	5

Source: Schwallier, 2012

2. Soluble solids content (SSC)

Sugars are the major soluble solids in fruit juices and therefore soluble solids can be used as an estimate of sweetness. A hand-held refractometer (picture 19) can be used outdoors to measure the percentage of SSC (equivalent degrees Brix for sugar solutions) in a small sample of fruit juice.

Refractometer

A refractometer is an instrument used to measure substances dissolved in water. It works using the principle of light refraction through liquids. As light passes from air into liquid it slows down. This phenomenon is what gives a “bent” look to objects that are partially submerged in water. Simply, the more dissolved solids the water contains, the slower light travels through it, and the more pronounced the “bending” effect on light becomes. Refractometers use this principle to determine the amount of dissolved solids in liquids by passing light through a sample and showing the refracted angle on a scale.

The most commonly used scale is referred to as the Brix scale. The Brix scale is defined as: the number of grams of pure cane sugar dissolved in 100 grams of pure water (grams sugar/100 grams H2O).

Picture 18: Refractometer

Source: Harrill, 1998

To use a refractometer:

1. Cut a slice of an apple between the fruit stem and the flower scar.
2. Lift the clear plastic cover of the refractometer, and squeeze apple juice on to the lens, without dropping pulp onto the lens.
3. Carefully lower the plastic cover onto the juice, making sure no pulp has fallen on to the lens, and no air bubbles are trapped between the plastic cover and the lens.
4. Look through the black eye piece towards the light source.
5. A scale becomes visible, where the percentage of sugars can be read from the scale.

Soluble Solid content (SSC)

- Mature fruits: 10 – 12 percent
- Immature fruits: 8 – 9 percent

6. Between tests or after use, rinse the lens and lens cover with water, and dry using a tissue. It is worth noting that testing the refractometer with plain water should give a reading of zero.

Table 3: Apple maturity guide by Brix level.

Brix guide	Low	Fair	Good	Excellent
All Apple Varieties	<11%	11%	12%	13%

Source: Schwallier, 2012

3. Fruit firmness test

The most common way to measure firmness is resistance to compression or pounds-force (lb-force). This is done using a fruit penetrometer (picture 20), which is a hand-held probe with a gauge for pounds-force.

Picture 19: Penetrometer.

To measure firmness:

1. Use fruits that are at room temperature neither warm nor cold, since warm fruits are usually softer than cold fruits. In addition to that, use fruits that are uniform in size, since large fruits are usually softer than smaller fruits.
2. Make two puncture tests per fruit on opposite cheeks, midway between stem and blossom ends.
3. Choose the appropriate plunger tip (size 11 mm for apples).
4. Hold the fruit against a hard surface, and force the tip into the fruit at a slow, uniform speed (take 2 seconds) to the scribed line on the tip.
5. Take the reading in lb-force.

• Apple firmness ~ 14 lb-force means that the fruit is suitable for immediate consumption.
• Apple firmness ~18 lb-force means fruits are suitable for long time storage.
• Apple firmness more than 18 lb force means that the fruit is still not mature.

Table 4: Suggested firmness levels for long-term and shorter-term storage by variety.

Variety	Firmness (pounds)*		
	Short term	Mid-term	Long term
Fuji	16	17	18
Gala	16	17	18
Golden Delicious	15	16	17
Red Delicious	16	17	18

Source: Schwallier, 2012

4. Number of days from full bloom

The period from full bloom to actual harvest is fairly constant for any given variety. The average number of days from full bloom to maturity in some apple varieties are as follows:
• Royal Gala: 125 to 135 days
• Red Delicious: 145-155 days
• Golden Delicious: 150-160 days
• Fuji: 180-190 days

Table 5: Number of days from full bloom to harvest by variety.

Cultivar /Rootstock	Number of days from full bloom to harvest
Fuji/M8	162
Galaxy Gala/M9	125
Granny Smith/M9	168
Early Red One/MM106	151
Red Chief/MM106	151
Scarlet Spur/MM106	145
Super Chief/MM106	151

Source: Bozbuğa and Pırlak, 2012

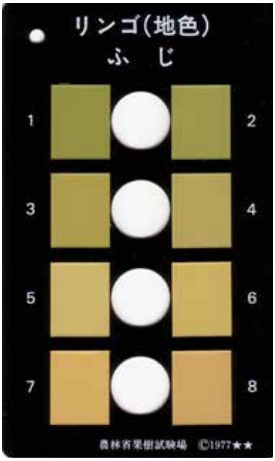
5. Seed color

The seeds of most apple cultivars turn brown when the fruit becomes mature and ready to be harvested. This is an unreliable index of maturity, because sometimes seeds become brown several weeks before proper picking maturity.

6. Skin color

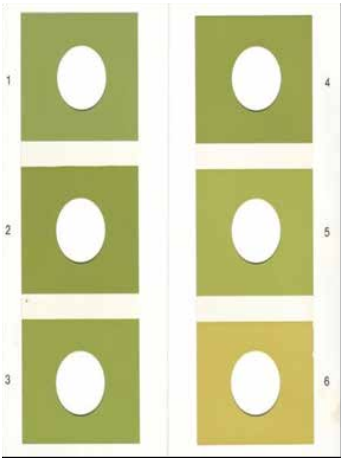
Development of red skin color in apples has limited value as its development is associated with the exposure of the fruit to light, temperature, and nutritional conditions in the tree. As a result, the entire surface of red apples may redden when the fruit is still immature. However, ground color changing from green to yellow are valuable with some cultivars. Using the apples' skin color as a guide to maturity is most economic, but also most subjective. Color measurements in apples can be done using visual comparison to color charts.

Picture 20: Fuji color chart.



Source: Kader, 1996

Picture 21: Golden Delicious skin color chart.



Source: Kader, 1999

Table 6: Maturity indices per apple variety.

Variety	Useful Maturity Indices	Not useful maturity indices
Gala	Ground color change from green to light green or white for white clones like Royal Gala.	Red skin color, firmness, soluble solids and acidity do not relate well to internal maturity for red clones like Gale Gala.
Fuji	Ground color change to light green or white; 180-190 days from full bloom.	Soluble solids have not been a useful guide because of variations. SSC can range from 12% in one year to 19% the next. Flesh firmness is also not a suitable harvest indicator.
Golden Delicious	Color change from dark green to light green or yellowish green; 150-160 days from full bloom; 12% SSC, 18 lb firmness; 20-40% of cortex free of starch.	
Granny Smith	Average starch score of at least 2.5 on the 6 pt California apple starch scale.	Year-to-year variation in fruit firmness, soluble solids and titratable acidity indicates that these factors are not useful maturity indices.
Red Delicious	11% SSC, 18 lb firmness; core clear from starch	

Source: Kupferman, 1994

Table 7: Recommended harvesting period for apple varieties in Lebanon (Zgharta)

Variety	Harvesting Period											
	August				September				October			
	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4
Early Golden												
Lyse Golden												
Golden Gibson												
Royal Gala												
Gala Gala												
Top Red												
Early Red One												
Ace												
Scarlet Spur												
Red Chief												
Super Chief												
Granny Smith												
Sun Fuji												

W1 = Week 1, W2 Week 2, W3 = Week 3 and W4 = Week 4.

Source: Nakad, 2005

Module 3: Cold storage operations

After harvesting and packaging the apple crates are either sent to the wholesale market or to the cold storage. In both cases, there are several practices that need to be done.

1. Managing temperature of apples

Cooling of fruits should first start in the field to reduce field heat and then continue in the cold storage. At the orchard during harvesting, the following should be done to aid in reducing the field apples' heat:

• Harvest at cool temperatures in the morning or night.
• Make frequent trips to the cold storage if possible; do not keep the apples in the orchard for too long.
• Pack in light color crates if possible.
• Cover crates to avoid sun burn and temperature build up.
• Stack the filled crates in shaded areas in the field.

Usually apples come from the orchard with a temperature of ~ 25°C., which is considered a high temperature. When these apples are put into a cold store with the previously cooled apples, the temperature of the cold storage rises.

Consecutive loads of field apple crates into the cold storage lead to continuous fluctuation in temperature. Variation of apples' temperatures during storage causes an increase in ethylene production and respiration that damages their quality and decreases their storage life. In order to avoid these problems, pre-cooling of the apples is necessary to completely remove field heat, before storing the apples into cold rooms.

1.1. Pre-cooling

Pre-cooling is a separate operation which is done before storage and complementary to it. Pre-cooling is the rapid reduction of field apples' temperature prior to storage and / or refrigerated transport. It is important as it reduces respiration and ethylene production in apples.

Degradation of apples is slowest at 0 °C but doubles for every 10 °C increase in temperature. Storage life is reduced between 4 to 30 days for every day the fruit is stored at ambient temperature; with different varieties reacting differently. Table 8 below shows the effect of increasing temperature on respiration and ethylene rates.

Table 8: Golden Delicious Respiration rates and Ethylene Production at various temperatures*

	Temperature	0°C	5°C	10°C	20°C
Respiration Rate	ml CO2/ kg·hr	3-6	4-8	7-12	15-30
Ethylene Production	µl/ kg·hr	1-10	2-25	5-60	20-150

*These rates are for mature, but not ripe fruit. Values increase with increased ripeness. Respiration is controlled by internal temperature sensitive enzymes that increase in activity from 2 to 4 times for each 10°C rise (up to 30°C).

Pre-cooling methods suitable for lebanese apples:
- Room cooling
- Forced-air cooling

1.1.1. Room cooling

Room cooling is widely used in Lebanon, as it is relatively low in cost, however it is a very slow method of cooling. The design and operation of cold rooms are fairly simple, fans should be installed to move the cold air throughout the room. Rooms more than 15 m long should contain ceiling ducts, the fan capacity should allow airflow of 3 m^3 / minute / ton of apples, and once cooled, airflow decreases to 0.6 – 1.2 m^3/minute/ton.

Room cooling involves exposing apple crates to cold air in a refrigerated or cold room where cold air is allowed to circulate among the apple crates. It is important to leave adequate space between stacks of crates inside the refrigerated room in order to allow the apples to cool faster. About 2.5 cm between each individual crate is sufficient to allow cold air to circulate. Apple crates inside the cold room should be stacked on a pallet, so that later it can be moved quickly to the cold storage with a forklift. Plastic crates used in Lebanon are well vented, but in the case that farmers used carton boxes, they should make sure to put the vents of the boxes facing each other in order to allow cold air to move between them. Moreover, there should be gaps between the pallets and the walls of the cold room. In Lebanon, in most cold rooms, apples have been loaded into the room so tightly that the apples' temperature never decreases to the recommended levels, where the lowest possible temperature for apples is -1.5 °C.

The responsible person for cooling has to monitor the temperature of the apples within the packages at various locations in the room (front, center and back, and different heights within the stack), to determine that the produce is being cooled as recommended.

1.1.2. Forced-air cooling

Forced-air cooling pulls air from the storage containers and replaces it with cold moist air thus greatly speeding the cooling rate of apples. The crates need special designed stacking on pallets in order to allow airflow. Pre-cooling using this method can cause water loss, for that reason, a humidifier should also be installed in the refrigerated room.

This system involves placing pallets of apples stacked in two parallel rows with a gap between the rows (tunnel) in the refrigerated room, while having the evaporator and humidifier turned on. Under the evaporator fan in the fridge, a false wall with a fan is installed. A canvas is rolled over all the way from the fan to the top of the apple crates and down to the floor at the end of the rows furthest from the wall. When the fan is turned on, a negative pressure is created thus moving the cold moist air through the apple crates into the tunnel. The hot air around the apple fruit will be forced out and replaced with cold moist air thus quickly cooling the fruit.

Picture 22: Forced-air pre-coolers before loading.

A pre-cooler showing:
- Cooling unit on the top (6 fans).
- Humidifier.
- False brown wall with fan to draw cold air from the room through the openings in the false wall.
- Canvas rolled and attached to the false wall.

Source: Hariri, 2010

Picture 23: Forced air pre-coolers after loading and before rolling the canvas.

A stacked pre-cooler showing:
- Two lines of cartooned fruit arranged facing the false wall.
- The gap between the two rows is called a tunnel.

Source: Fraser, 2014

Picture 24: Forced-air pre-cooling after loading the boxes and after rolling the canvas (ready to operate the precooling).

A stacked pre-cooler showing:
• A cover is placed over the top of the two lines of cartons, and over the end of the lines furthest from the wall.
• Cold air from the room is pulled through ventilation holes in the cartons, into the gap in the false wall, and out through the fan vents above.

Source: Fraser, 2014

1.2. Cold storage

Cold storage is by far the most effective method of preserving quality and extending shelf life of apples. Cold storage slows the biological activity of apples, growth of microorganisms, reduces the rate of moisture loss, and reduces the damage from ethylene gas. Apples should be pre-cooled prior to loading into cold storage rooms. If pre-cooling is not available, the daily influx of apple crates into the cold store should not exceed 10 percent of the cooling capacity of the room. If apples are to be stored, it is important to begin with high quality fruits, free of bruises and diseases. It is uneconomic to add the cost of storing poor quality apples to the overall storage cost. Depending on the variety, apples can be stored for up to 12 months.

Farmers should measure fruit firmness before storage:
• Apples with firmness level above 18 lb., have the longest storage life and should be stacked furthest from the cold storage door.
• Apples with firmness levels less than 15 lb., have shorter life and should be closer to the door.
Cold rooms should be brought down to the appropriate temperature for about three days prior to loading with the produce. Rooms without floor insulation may take a week to reach the desired temperature. It is worth nothing that failure to pre-cool the cold room may cause slow cooling and excess water loss from the produce.

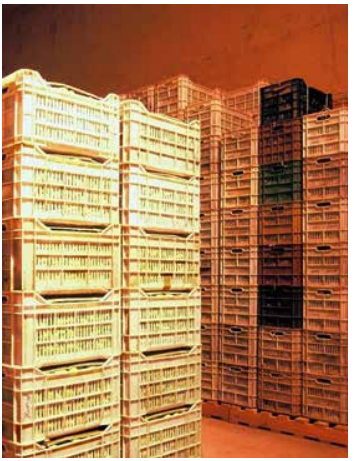
All crates should be stacked on pallets and labeled with the apples' variety, source (by orchard owner), quantity, harvest date, packing date, pre-cooling method used, storage entry date and any special handling procedures.

These records are important in identifying problems associated with one particular farmer, variety and orchard during storage.

Storage room should be disinfected with a 0.25 percent of sodium hypochlorite solution applied with a high-pressure washer.

Proper storage practices include temperature control, relative humidity control, and adequate ventilation (air circulation).

Picture 25: Apple crates stacked on pallets.



Source: Nakad, 2005

1.2.1. Temperature

Temperature is the most important factor that determines the rate of apple deterioration. Optimum temperature to store apples is 0°C. Cold storage rooms must be equipped with thermometers for temperature measurement, thermostats to control the operation of refrigeration units, and manual temperature controls that must be periodically checked. Temperatures should be recorded in several places within the cold store during the storage period, and monitored carefully. Errors of only a few degrees in temperature will negatively affect the quality of the fruit. Alternating cold and warm temperatures within the cold store can result in the accumulation of moisture on the surface of produce (sweating), which may stimulate decay.

When calculating refrigeration cooling capacity for the apples' cold storage the following information is needed:
Apples produce heat in storage due to respiration.
• At 0° C, 1 ton of apples produce 750 BTU of heat.
• At 10° C, 1 ton of apples produce about 2000 BTU of heat.

Temperature management during storage can be aided by:

• Location of the cold storage, where establishing a cold storage facility at high altitudes is most effective and feasible, since air temperature decreases as altitude increases.

• Shading and/or painting the storehouse's roof with white color to reflect the sun's rays have cooling effects. Similarly, wetting the storage's roof for evaporative cooling by using sprinkler systems will have cooling effect too thus the refrigeration units will operate less.

• Insulating the floor of the cold storage, where the floor should be concrete and insulated with polyurethane foam to prevent slow cooling of the cold storage.

• The door of the cold storage should have a rubber seal around the edges.

• The walls of the cold storage should have tightly sealed joints between the sandwich panels of the prefabricated cold storage to prevent cooling loss.

1.2.2. Relative humidity

Relative humidity (RH) of 90 to 95 percent is optimal for most types of apples. RH should be controlled in order to ensure that apples will not dehydrate; which causes losses in both the quality of the fruit and its weight. RH also affects uniformity of fruit ripening, decay development, and the incidence of some physiological disorders.
RH within the cold store can be controlled using a humidistat and can be monitored using a recording hygrometer.

RH can be increased by:

• Adding moisture (water mist or spray) to air with the use of humidifiers.
• Wetting the floor of the cold storage room.

1.2.3. Ventilation system

A ventilation system should be set while cooling to create an air flow rate of 100 cfm/ton (5 L/sec/ton). Crates must be well ventilated and stacked in a way that ensures even distribution of cool air throughout the room and around the crates while stacked on pallets. Once recommended cooling temperature has been reached, air flow rates should be decreased to the lowest speed that will keep produce cool (20 to 40 cfm/ton is usually sufficient). There should be a minimum gap of 8 cm between the stacks of produce and the walls of the room. In addition to that, a minimum gap of 10 cm between the floor and the stack is required, as well as a minimum of 20 cm between the cooling evaporators and the top of the stack.

1.3. Controlled atmosphere

In a controlled atmosphere, other than controlling temperature and relative humidity, the composition of the air inside the cold storage should also be controlled, in particular the levels of oxygen and carbon dioxide; as well as the removal of ethylene gas from the cold storage room.

Requirements for controlled atmosphere storage:
• Gas-tight refrigerated storage room.
• Equipment to create the recommended gas concentration.
• Equipment to measure and control the atmospheric composition.

A controlled atmosphere means adding or removing gases resulting in an atmospheric composition surrounding the apples different from that of the air which is: 79 percent of nitrogen, 21 percent of oxygen and traces of carbon dioxide ~ 0.03 percent. This involves reducing normal levels of O2 to 0.7 - 3 percent and elevating CO2 levels to 0.5 - 4 percent in a perfectly sealed cold storage room to. This leads to:
• Reduction of apple respiration rate and inhibiting ethylene production, thus retards ripening and prolongs the storage life.
• Reduction of certain physiological disorders such as chilling injuries.
• Reduction of pathogens and insect control.
• Minimize post-harvest disorders in stored apple fruit, such as Bitter Pit (Picture 4), and Storage Scald.

The use of controlled atmosphere is a commonly used practice, but it is highly technical. For example, different varieties of apples react differently to differing levels of oxygen/carbon dioxide. Cold storage managers, dealers, or farmers who want to consider these systems should seek technical advice from specialists.

Potential harmful effects of using controlled atmosphere:
• Causes or worsens physiological disorders in apples, such as brown hearts.
• Irregular ripening of fruits.
• Induction of off-flavors/odors: very low O2 and very high CO2 concentrations can cause anaerobic fermentation leading to alcohol formation that causes off flavors and tissue breakdown.
• Increase in decay susceptibility.

Table 9: Recommended temperatures and CA for storage of selected apple varieties.

Cultivar	Temperature°C	% O2	% CO2	Storage life (months)
Apple in General	0.9	1.7	2	
Golden Delicious	0.5	1.6	2.3	7 – 10
Red Delicious	0	1.6	1.8	6 – 11
Fuji	0.3	1.4	1	7 – 11
Granny Smith	0.6	1.4	2	7 – 11
Royal Gala	-0.2	1.7	1.8	5 - 8
Gala	1.3	1.7	1.6	2 – 9

Source: Kitinoja and Kader 2002

Module 4: Transportation

Every handling step in the supply chain involves some form of transport. Then the worker who harvests the apples must transfer the apples to field crates that are then moved to wholesale or retail markets or to a packing house located off farm. Within the packing house, the apple crates should be moved into cold storage before they are sorted, graded and packed. The packed boxes are then assembled into pallets. Palletized loads may be moved into cold rooms for storage or into precooling rooms before loading them into refrigerated trucks for export. On arrival at their destination, these loads of apples will be transported to retail outlets. The last transport step of the chain is from the retail store to the consumer's home. Quality can be compromised at every handling step because of physical injury, rough handling and incorrect management of temperature.

1. Transport at farm level

At this level, apples are susceptible to mechanical injury and must be handled with care. Impact, compression, and vibration damage may be initiated at the farm during transportation. Apple crates should be kept out of the sun and moved rapidly to a shaded collecting area in the field or directly to the packing house via pickups.

Causes of impact damage (e.g. bruise, crack, split, cuts):
• Small crates should be used for collecting apples. The total weight per crate should not exceed 20 kg so that it can be carried easily by workers.
• Dropping or throwing filled crates into the pickup: crates should be gently loaded into pickups for transport to the packing house.

Causes of compression damage:
• Overfilling crates with apples.
• Stacking crates too high in the pickup.
• Stacking crates over each other without putting carton to separate the crates.
• Standing on the crates during loading or unloading.
• Loading using un-uniform crates.
• Crates that are not braced tightly to prevent damage.

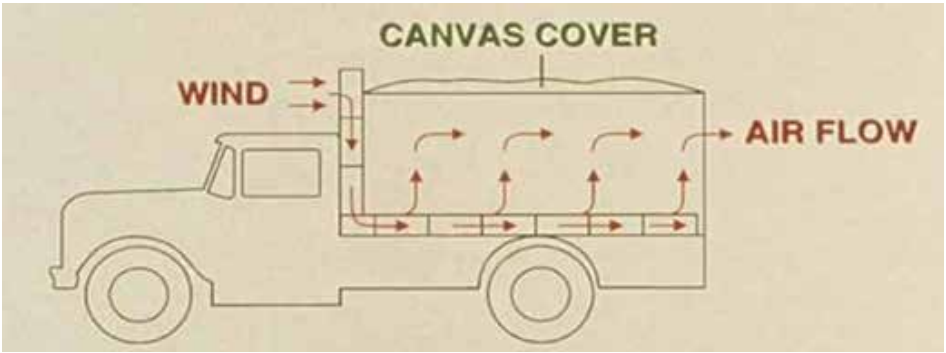
Causes of vibration damage:
• Under-filling of crates.
• Poor suspension system of the pickup and when the wheels are over filled with air.
• Rough roads or quick driving.

2. Transport to local markets

This level is usually done by non-refrigerated transport – or pickups. Transport of cooled apples using this method should not exceed six hours to prevent reheating. The driver should consider traveling at night or early morning before sunrise.

Pickups should have the following specifications, (example seen in Picture 30):
• A light-colored shade with side curtains made from waterproof canvas to avoid exposure to the sun, rain, and strong air flow that could dry out the apples.
• A wind catcher for moving air into the pickup during transport.
• Channels for passive air movement beneath and up through the load.

Picture 26: Wind catcher and ventilation ducts..



Source: Kitinoja and Kader 2002

3. Transport to export markets

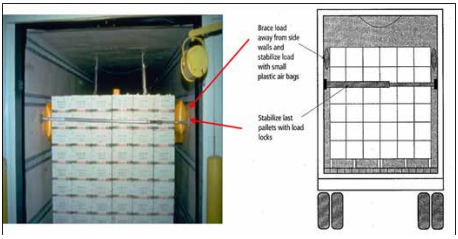
This level is mainly done by refrigerated trucks or trailers. Refrigerated trucks are designed to maintain temperature, not to remove the field heat associated with apples. Apple boxes must be pre-cooled to 0-1°C before loading, and trucks used for loading should be pre-cooled to 0-1°C. The loading process to trucks must be done rapidly (20 to 30 min) using a forklift.

The packed pallets must be loaded properly to prevent in-transit displacement of pallets. Shifting of crates in the pallets during transportation can cause serious damage to the fruit. Driving must be gentle and slow to avoid sudden heavy braking that might knock the apples around causing bruises.

For that reason trucks should be:

• Equipped with air bags in order to reduce road shocks and vibration to the produce (Picture 28).

Picture 27: Air bags on the sides of the truck and load lock at the back.



Source: Kader, 2011

• Equipped with wooden braces (Picture 29) or load locks (Picture 28) to support the load at the end. The key is to immobilize stacked produce to reduce damage during transport.

Picture 28: Wooden braces or rear-door bracing at the back of the trailer.

Source: Tiger Cool Express, 2014

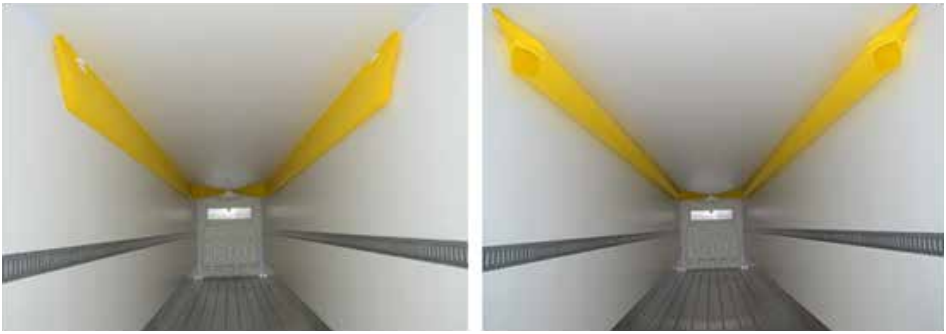
• Equipped with floor channels: refrigeration systems are designed to stop heat entering through the walls and warm air leaking from the doors. They are designed to blanket the produce with cooling air. Floor channels are to ensure that this blanket of cooling air is complete. There must be an air gap between the walls of the refrigerated truck and the produce. This can be achieved by the bulkhead at the front of the unit that allows unrestricted flow of return air to the heat exchanger. Similarly, there should be a clear gap between the rear of the load and the doors of truck. For that reason bracing the pallets at the rear is necessary. Floor channels carry return air back to the refrigeration unit, where these channels must not be obstructed and must be kept clean (Picture 30).

Picture 29: Floor Channels.

Source: Tiger Cool Express, 2014

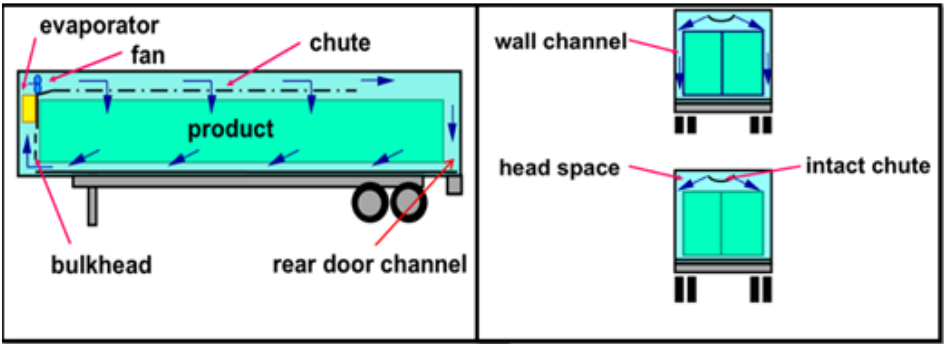
• Equipped with Chute: There must be an air delivery chute extending two thirds the length of the truck which is more than six meters long. This air delivery chute must be mounted on the ceiling (Picture 31). Picture 32 illustrates the desired air flow inside a refrigerated transport load.

Picture 30: Air delivery chute extending two thirds of the length of the truck.



Source: Tiger Cool Express, 2014

Picture 31: Desired air flow inside a loaded refrigerated truck.



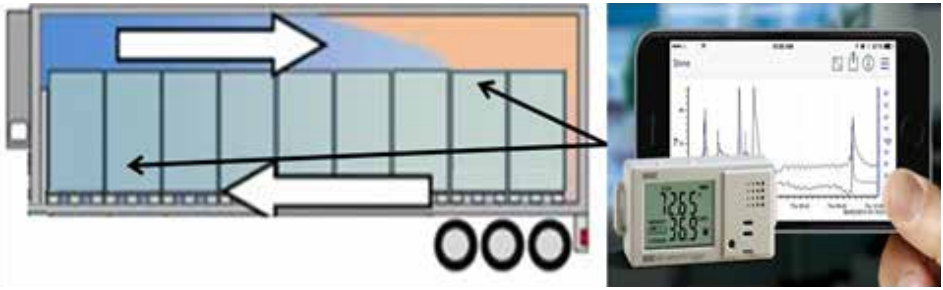
Source: Pacific International lines, 2016

4. Portable temperature data loggers during transport

Delivery and return air temperatures are continuously monitored and are used to thermostatically control the refrigeration unit. Many exporters insist that temperatures should be recorded throughout transportation period to ensure that apples arrive in optimum condition. If the apples arrive in a poor condition, the temperature records can be vital in settling disputes between transporters and exporters.

This can be done by inserting at least two portable temperature data loggers into the boxes of apples to record produce temperatures during transit. One should be located in the front bottom of the load to measure the temperature of the return path air, and the second should be located at the rear middle of the load.

Picture 32: Preferred location of portable temperature data loggers into boxes in cooled trucks.



Source: Onset Computer Corporation, 1995

5. Refrigerated trucks pre-loading checklist

For optimum transport temperature management, exporters should inspect the truck before loading the apple boxes. The checklist below includes important features in a top-air delivery trailer:

- Is the refrigeration unit operating properly?
- Is the thermostat calibrated?
- Are the refrigeration air chutes and ducts properly installed and in good condition?
- Are the door seals in good condition?
- Do doors seal tightly when closed?
- Are the walls free of cracks and holes?
- Is the front bulkhead installed?
- Are the floor's channels open?
- Are the floor's channels free of debris and clean?
- Is the inside of the container clean and odor-free?
- Is the inside of the container (height, width, length) adequate for loading?
- Are the load braces and other devices available to secure load?
- Is the vehicle trailer pre-cooled?

Module 5: Food safety in the apple sector

In Lebanon, there are no available documents that highlight the guidelines for apple produce food safety. The Lebanese Standards Institution (LIBNOR) has not issued yet any norm related to this topic. For this, the information presented in this part was compiled from international references.

1. Good Agricultural Practices (GAP)

Food safety is a responsibility shared by everyone, including producers, processors, transporters, retailers and food service providers. In several developed countries, supermarket chains are increasingly demanding that their suppliers be certified against a private food safety standard, such as GAP. GAP are farming practices which have been developed in recent years by the food industry, producers' organizations, governments, and NGOs. They focus on preventing contamination of fruits and vegetables on the farm. They are voluntary audits that verify that crops are produced, packed, handled, and stored as safely as possible to minimize risks of microbial food safety hazards. Taking reasonable steps to prevent a problem in the first place often costs far less money and time and is more effective than trying to fix a problem after it emerges. Just as farmers tailor crop production and pest management practices for their particular operations, farmers should tailor GAPs to the specifics of their farms.

2. Food safety hazards associated with apples

Raw fruits and vegetables shall be thoroughly washed in water to remove soil and other contaminants before being cut, combined with other ingredients, cooked, served, or offered for human consumption in READY -TO-EAT form." - FDA Food Code; Chapter 3.302.15

According to CDC, one-third of all significant outbreaks of foodborne illnesses involve fresh produce.

Hazard analysis

What is Hazard analysis?

• It is the first step in being proactive, regardless of the standard of operations and level of perceived potential risk
• It is the baseline of any food safety program
• It involves identifying and assessing hazards
• It should be updated every time a significant change is made to inputs. A change may reduce or eliminate a hazard, increase the risk of a hazard, or introduce a new hazard

Once hazards are identified, risk should be assessed by determining the level of likelihood and severity . RISK = LIKELIHOOD x SEVERITY
Severity may be:
1. Not significant / 2. Customer complaint / 3. Product recall / 4. Serious illness / 5. Fatality

Likelihood may be:
1. Practically impossible / 2. Not expected to occur / 3. Could occur / 4. Known to occur / 5. Common occurrence

Table 10: Matrix for assessing the significance of a hazard, based on both the likelihood of the hazard occurring and severity of impact it does.

Likelihood					
Severity	**1**	**2**	**3**	**4**	**5**
1	L	L	L	L	L
2	L	L	L	L	H
3	L	L	L	H	H
4	L	L	H	H	H
5	L	H	H	H	H

Source: Guidelines for Fresh Produce Food Safety (2015) Fresh Produce Safety Center, Australia and New Zealand

Accordingly, risk values range between 1 and 25. Risk is considered "low" when its value is between 1 and 9, while it is considered "high" when its value is between 10 and 25. A physical hazard, such as soil, has a likelihood of 5 since it is very common in crops; however, its severity is 1 since it is not significant, making its risk level low.

Example: There are reports of abusing pesticide use among farmers in Lebanon. The hazard, which is the pesticide residues in this case, has a likelihood of 4. Pesticide residues are not fatal and in the same time, their effect on health cannot be negligible. In this case, a severity level of 3 can be given. As such, the risk of this hazard = 12 (4 x3), which is considered high.

Microbial contamination (biological hazards)

Most microbes are harmless, some are beneficial and others are the cause of food spoilage and rots in fruits and vegetables. In fact, in all cases fruit carries between 103 to as much as 107 microorganisms. Only a very small percentage of the microbes are pathogenic (disease causing). Examples include *Escherichia coli*, *Salmonella* sp. and *Listeria* sp. (bacteria), hepatitis A and norovirus (viruses). The most common symptoms associated with clinical microbial contamination are nausea, diarrhea and vomiting (gastroenteritis, or 'gastro'). It is worth noting that immunocompromised consumers (e.g. infants and old people) are more susceptible to microbial contamination.

Preventing contamination is the best way to ensure crops are safe to eat. However, if contamination does occur, the likelihood that it will cause illness partly depends on the physical attributes of the product and how it is prepared and eaten. In the case of apples, there are natural openings (calyx) that allow microbes to enter or openings caused by damage.

Examples of questions to consider when assessing risk of apples include:

- How is the product consumed, cooked or uncooked?
- What part of the product is eaten, peeled or unpeeled?
- How long will the product be stored before it is eaten and under what conditions?

Picture 33: Presence of waste in the field contaminates the crop.

Source: Guidelines for Fresh Produce Food Safety (2015) Fresh Produce Safety Center, Australia and New Zealand

Physical hazards

Physical contaminants in fresh produce are frequent and of concern to supply chain stakeholders. Examples include soil, wooden pieces, hair, and screws. They are a regular cause of consumer complaints, recalls, withdrawals, and negative media coverage. Physical contaminants are usually introduced during production and packing. Staff training is crucial to address this issue, in parallel with effective policies and procedures. Prevention is the key. Detection and removal methods, such as in-line magnets for removing metal fragments, are vital as well.

Chemical contamination

There are many potential sources of chemical hazards to fresh produce, including pesticides. But, some chemical hazards are naturally occurring, such as allergens. There are many different types of chemical hazards including pesticide residues, heavy metals, natural toxins, non-pesticide contaminants, and allergens.

Wax

The most commonly used wax is Carnauba wax (E 903) which is sourced from the leaves of a Brazilian palm tree and is safe to eat. Other approved waxes include beeswax E901, shellac E904, white mineral oil E905a, and petroleum jelly E905b.

Patulin

Patulin is a mycotoxin that is produced by certain types of molds (*Penicillium*, *Aspergillus* and *Byssochylamys*) that may grow on apples and pears.Though a direct connection has not been made to humans, patulin has been found to cause a range of health problems in laboratory animals including: harm to fetuses

(mutagenic), problems with the immune system, and bleeding in the brain. There is concern that similar effects may occur in humans, which is why exposure should be kept as low as practically possible.

Patulin is most likely to be a problem in apples or pears with bruises, rot or other surface damage. Patulin may be a more serious problem when using apples that have been stored for a longer period of time. FDA believes that control by processors of patulin levels to an action level of 50mg/kg or below can be achieved principally by inspecting and removing spoiled and/or visually damaged apples. A washer-brusher will also help remove the rot and soft spots that may contribute to patulin formation.

Heavy metals and Persistent Organic Pollutants (POPs)

Contamination of apples with heavy metals are mainly due to the irrigation with contaminated water, the applications of metal-based pesticides and fertilizers, and the harvesting process and storage. Consumption of apples contaminated with heavy metals can cause bone fracture, kidney dysfunction, hypertension, and even cancer.

POPs are toxic organic chemicals, after release into the environment, they remain intact for exceptionally long periods of time and become widely distributed throughout the environment. POPs accumulate in the fatty tissue of humans resulting in cancer, allergies, and damage to the central and peripheral nervous systems. In Lebanon, these are expected to exist in high levels due to pollution and garbage incineration.

3. Managing water

Hazards and sources of contamination

Water can be a source of both microbial and chemical contamination of apples. It is therefore essential to manage the water used in many steps of the supply chain in order to supply safe produce to consumers. Water acts as a medium for spreading pathogens. Whole batches of apples may be contaminated if water-borne microbes infiltrate the products or adhere to the product surfaces. Many of the foodborne illness outbreaks that have occurred globally have been traced to the use of contaminated water. Contamination can occur directly through water contacting produce, it can also occur indirectly from contaminated water used to clean containers, equipment, tools, facilities, vehicles, and workers' hands.

Water sources vary in quality and change over time. Seasonal changes due to rainfall and temperature also affect water quality. Generally, the risk of contamination is highest for surface water supplies, less for ground water supplies, and lowest for domestic water supply.

Factors to consider when assessing the risk of contamination are:
• Type of water source: surface water, ground water, or domestic supply.
• Proximity of source to septic or sewage systems.
• Proximity of source to sources of pollution such as garbage dumps, manure storage, manured areas, or intensive livestock.
• Bird and/or animal activity.

Areas used to store chemicals or fertilizer should be located away from water sources and bunded to contain potential leaks or spills. Water may flow directly from its source to the point of use or be stored in tanks prior to use. Beware that water pipes and tanks can become sources of microbial contamination. Best practices include:
• Water pipes: Water pipes are well maintained and free from breaks and cracks that might allow entry of microbes. It is important to regularly clean application points, such as spray nozzles.
• Storage tanks: The tank is constructed to prevent entry of pests, wild and domestic animals, and birds. Therefore, a filter is fitted to prevent plant material and other debris from entering the tank.

Water used during harvesting, packing and distribution

Washing

Most contaminants are on the surface of produce, which means they can spread to surrounding produce thus increasing the hazard. Washing produce can reduce the likelihood of microbes and chemicals remaining on the surface, but must be effective:
• The washing process must be thorough enough to remove soil, chemicals, and foreign bodies.
• Vigorous washing increases the chances of removing microbial or chemical contaminants.
• Continuously recycling wash water increases the risk of microbes and chemicals accumulating, and contaminating produce and equipment.

Water containing *E. coli* <1 cfu/100ml should be used in direct contact with apples upon washing, however water containing *E. coli* <100 cfu/100ml should be used in indirect contact with apples upon cleaning vehicles, floors, walls, and ceilings of the facility.

When warm apples are placed in cold water, the internal tissues cool and contract, drawing water and microbes inside. Water can infiltrate the inside of an apple through the calyx. Internalization is prevented if the dip or flume water is at least 5°C warmer than the product.

Fungicides and insecticides do not kill pathogens. Contamination of the pesticide dip or spray may lead to contamination of the apples. Treatment tanks must therefore be sealed to prevent entry of birds, rodents, and other animals.

The water used to dilute waxes can be a source of contamination. As waxing is usually the final treatment, water containing *E. coli* <1 cfu/100ml must be used. Furthermore, water used for cleaning picking containers, vehicles, facility (floors, walls, and ceiling) and equipment that contacts produce, should be discarded after use.

Water sanitizers

• Calcium hypochlorite (solid) and sodium hypochlorite (liquid)
• Bromo-chloro dimethylhydantoin
• Chlorine Dioxide (gas)
• Peroxyacetic Acid (PAA)
• Hydrogen peroxide
• Iodine
• Ozone

E.Coli limits

Water is treated to achieve the critical limit of E.coli <1 cfu/100ml of water unless:
• The fresh produce being treated is always eaten cooked.
• The water is used to pre-wash produce before a final wash in better quality water.

Water sources used are tested monthly during the period of use or annually once it is historically proven to achieve the critical limit (at least 4 consecutive tests below the limit).

Water outlets are clearly marked e.g. 'not for drinking or hand washing' if they supply water not verified as *E.coli*<1 cfu/100ml.

Reducing risk

Select, manage, and maintain water sources, water storage equipment and infrastructure to minimize potential contamination from:
• Human activities
•Livestock and domestic animals
•Wildlife (where possible)
•Adjacent activities

Water sources contaminated by toxic algae should not be used, and water in recirculation systems, water dumps, flumes, and treatment tanks is changed at an appropriate frequency.

Hazard analysis

A process flow diagram is prepared to identify where water is used and its source. Moreover, a hazard analysis is conducted to determine the risk of microbial contamination of produce from each water source in use, and a record of the analysis is kept.

Factors to consider include:
• The type of produce
• How it is consumed
• Potential causes of contamination
• The likelihood of the water being contaminated
• How the water is used

Sanitation

If the hazard analysis determines the significance of the hazard as high, a safe alternative water source should be used, or the water should be treated to reduce the microbial load. In addition to that, water sanitation treatments are monitored to verify effectiveness and check that operating conditions are maintained. Monitoring is at a frequency consistent with the risk and results are kept.

Potential sources of contamination from chemicals used during harvesting, packing and storage.

Food safety hazard	Potential sources of contamination
Pesticide residue in produce exceeding maximum residue limit (MRL)	• Not reading/understanding the pesticide label. • Pesticide applied incorrectly to the product, or incorrect product being used. • Pesticide not stored correctly or expired. • Incorrect dilution-concentration higher than label rate. • Withholding period not observed. • Equipment incorrectly or not calibrated.
Non-pesticide contamination	• Spray drift contamination from neighboring crop. • Persistent pesticides remaining in soil from previous use. • Pesticide residue in picking bins, crates, and water dump tanks. • Equipment (including personal protective equipment) not cleaned after use especially if used for multiple purposes. For example, both washing and spraying. • Pesticide or surface coating used during the post-harvest stage, but not approved for that use pattern. • Spray drift contamination from neighboring area or industrial site. • Cleaning and pest control chemicals not appropriate for use. • Spillage of chemicals near produce, equipment, containers, and packaging materials. • Fruit and vegetable waxes that include components not approved in the destination market e.g. morpholine, which is prohibited in Europe. • Items included with packed product which are not appropriate to that use (e.g. leaky sulfur pads, ethylene absorbents).

Source: Guidelines for Fresh Produce Food Safety. Fresh Produce Safety Center, Australia and New Zealand

4. Managing chemicals

Best practices

Purchase

• Chemicals that are sourced from approved suppliers.
• Chemicals that are properly labeled.
• Deteriorating chemical labels should be replaced immediately with a legible copy.

Storage and disposal

Chemical storage areas are:
• Located and constructed to minimize the risk of chemicals contaminating produce directly, or indirectly through contamination of water sources.
• Structurally sound, ventilated, adequately lit, and constructed to protect chemicals from direct sunlight and weather exposure.
• Constructed to contain chemical spills and equipped with a spill kit.
• Secure, with access restricted to authorized workers.

Chemicals are stored in designated separate areas for each category of chemical (e.g. insecticides, fungicides), and for chemicals awaiting disposal. They should be stored in original containers according to directions on the container label. If a chemical is transferred to another container for storage purposes, the new container must be a clean chemical container approved for the relevant product (e.g. Dangerous Goods). It is important to transfer a copy of the chemical label to the new container.

A check is conducted at least annually to identify and segregate chemicals for disposal that have exceeded the expiry date or for which registration has been withdrawn. Moreover, A record of the check is kept, including the date of the check, and the name and quantity of chemicals awaiting disposal. In addition to that, an accurate inventory of chemical storage facility contents is maintained and available to emergency services in case of fire or theft. It is important to legally dispose of any unusable chemicals and empty chemical containers e.g. registered collection agencies or approved off-farm disposal areas.

Training

Workers involved in the supervision of the use of chemicals have successfully completed a recognized chemical users course or equivalent. Moreover,
workers authorized to use chemicals have been trained and are supervised appropriately.

Use pattern

• Chemicals are used and applied according to regulatory and customer requirements, and label directions.

• Copies of current chemical labels and off label permits are kept (permits available from the Australian Pesticides and Veterinary Medicines Authoroty APVMA website).

• Chemicals are checked for label changes when opening each new container.

• Chemical application equipment is kept well maintained and checked for effective operation before and during each use.

• Equipment is calibrated according to manufacturer's instructions or at least annually. Calibration must always be tested immediately after spray nozzles are replaced.

• Equipment is calibrated using a recognized method and a record of calibration is kept, including the date and person conducting the calibration, a description of the method, and the calibration results.

• Chemical mixing areas are located to minimize the risk of contaminating produce directly, or indirectly through contamination of water sources.

• Leftover chemical solutions are disposed of according to label directions where specified, or in a manner that minimizes the risk of contaminating the produce.

Records of use

Records kept of all chemical treatments should include:
• Growing site treated (address).
• Treatment date and start/finishing times.
• Target pest.
• Produce treated.
• Chemical used (including batch number).
• Rate of application and the quantity applied.
• Equipment and/or method used to apply the chemical.
• Withholding Period (WHP) where applicable.
• Name of the person who carried out the chemical treatment.
• Nozzle size and operating pressures.
•Weather: humidity, temperature, and wind direction. In addition to any other information related to spray drift restraints as required by APVMA approved label.

Testing

A random sample of packed produce ready for sale and/or consumption is tested at least annually to verify that chemicals have been applied correctly.

Chemical residue levels should not exceed Maximus Residue Limits (MRLs) as specified by Food Standards. The chemical residue test is a multi-screen test that includes pesticides used. It is conducted by a laboratory with accreditation to ISO/IEC 17025 for the analysis of chemical residues.

Picture 34: Storage of chemicals..

Source: Guidelines for Fresh Produce Food Safety (2015) Fresh Produce Safety Center, Australia and New Zealand

Picture 35: Storage of pesticides..

Source: Guidelines for Fresh Produce Food Safety (2015) Fresh Produce Safety Center, Australia and New Zealand

5. Managing facilities

Potential sources of contamination from the outside environment:

Facility environment	sources of contamination
Water storage	Facility water source contaminated by feces from birds, rodents, and other animals
Drainage	Microbes from puddles and poorly drained areas enter the facility directly by runoff or carried in on machinery, equipment, and workers
Roads and paths Farm machinery and vehicles	Soil and dust enter the facility by wind, equipment, and workers
Farm machinery and vehicles	Soil and pests enter the facility on tractors and forklift wheels
Equipment and containers	Transfer of soil and plant debris into the facility on equipment and containers used during growing and harvesting
Livestock and pests	Entry of birds, rodents, and other animals into the facility, Microbes enter the facility directly by wind and runoff or carried in on machinery, equipment and workers
Storage of fertilizers, manures, and chemicals	Microbes and chemicals enter the facility directly by wind and runoff or carried in on machinery, equipment and workers (storage not well separated from the facility)
Facility surrounds	Weeds and plant wastes near the facility harbor pests
Toilets and worker meal areas	Sewage and wash water seep into the facility water source or runoff directly into the facility

Potential sources of contamination inside packing and storage facilities:

Facility structures and areas	Potential Sources of contamination
Structures e.g. walls, ceilings, posts, bearers, mezzanine floors, walkways, stairs	Paint flakes, rust and dirt on structures fall into open containers or packed product Feces of birds, rodents and other animals accumulate on structures and drop onto produce, equipment, containers, and packaging Water drips or splashes from structures during cleaning or from leaks during heavy rain Electric insect killers that attract and kill flying insects which then drop into grading equipment or onto produce
Cool rooms, ripening rooms	Dripping of water from dirty ceilings, walls, and cooling units into open containers Splashing of water onto produce during cleaning
Lights	Glass from broken lights falling onto produce, equipment, containers or packaging materials
Storage of equipment and materials	Feces of birds, rodents, and other animals accumulating in storage areas Glass, hard or brittle plastic, ceramic, or similar materials falling onto produce, equipment, containers, and packaging
Chemical storage	Spillage or leakage of chemicals into areas where produce is handled and/or packaging is stored
Storage of equipment and materials	Spillage or leakage of fuel, oil, and grease into areas where produce is handled and/or packaging is stored
Fertilizer storage	Spillage or leakage of fertilizers into areas where produce is handled and/or packaging is stored
Workshop	Metal shavings and other foreign objects from a workshop located close to areas where produce is handled and/or packaging is stored
Workers	Jewelry, hair, Band-Aids

Best Practices

• Entry of soil, dust, water, and other potential contaminants from the outside should be minimized or managed.

• Facility structures must be kept clean and well maintained; free of vermin, insects, and spiders.

• Produce should be separated from storage areas for chemicals, fuel, fertilizers, or other potential contaminants.

• The layout of the facility should prevent contaminants from earlier steps in the process (e.g. arrival and pre-wash) entering later steps in the process (e.g. packing and storage).

Source: Guidelines for Fresh Produce Food Safety. Fresh Produce Safety Center, Australia and New Zealand

Picture 36: Ensuring cleanliness of the facility is required.

Source: Guidelines for Fresh Produce Food Safety (2015) Fresh Produce Safety Center, Australia and New Zealand

6. Managing equipment and tools

Potential sources of contamination from harvesting and packing equipment:

Food safety hazard	Sources of contamination
Microbial	Feces of birds, rodents and other animals on equipment Contaminated produce, soil and other debris on tools and equipment Tools and equipment cleaned with contaminated water Equipment dripping contaminated water Splashing of contaminated water during cleaning of tools and equipment
Chemical	Grease and other lubricants touching produce Use of inappropriate cleaning and sanitizing products on equipment or tools Accidental spillage of pesticides, fuel, oil and other chemicals
Physical	Metal shavings, bolts, nuts, glass, plastic fragments, knife blades, insects and other foreign objects from damaged or poorly maintained equipment mixing with produce

Source: Guidelines for Fresh Produce Food Safety (2015) Fresh Produce Safety Center, Australia and New Zealand

Equipment design is important to minimize the risk of contamination. Preventative maintenance is important to minimize the risk of physical contamination. Furthermore, lubricants should be used with care, and tools used by workers must be controlled.

Knives must have solid blades and only be issued to staff by an appropriate manager. In high-risk situations, knives should be numbered and the date and time of issue should be recorded in a dedicated log book. After use, all knives should be returned to the appropriate manager and inspected for damage. Lost or damaged knives must be accounted for. Moreover, the knife condition, return date, and time should be recorded in the log book, and knives must be locked away when not in use.

A cleaning and maintenance plan should be prepared describing each type of equipment, the method and frequency of cleaning, and maintenance activities. A procedure should be established for all cleaning and maintenance activities to ensure they are done correctly and as scheduled.

Cleaning and sanitation

Cleaning involves using a detergent or high pressure water to dissolve and remove dirt. Cleaning reduces the number of microbes on a surface by removing the dirt to which they are attached. Detergents do not have any residual effect on remaining microbes.
To be effective, a number of factors must be considered:
• Type of detergent
• Type of surface to be cleaned
• How the detergent will be applied to the surface
• Effectiveness of the detergent in the quality of water to be used

The purpose of sanitizing is to significantly reduce the number of viable microbes that remain after cleaning. A sanitizer will reduce the number of microbes but will not kill all of them. Sanitizers that can be used on surfaces and equipment include the following active constituents:
• Chlorine
• Iodine
• Quaternary Ammonium Compounds (QACs)
• Alcohol
• Peroxyacetic acid
• Acid anionics
• Carboxylic acids

To be effective, a number of factors must be considered:

• The surface to be sanitized should be physically clean.
• The sanitizer needs to directly contact the surface.
• Sanitizers are more effective at high rather than low temperatures.
• Concentration and duration of contact time.
• Quality and PH of water used with the sanitizer.
• Number and type of microbes to be controlled.

The detergent and sanitizer must be chosen to suit the purpose and be approved for use on food contact surfaces. Even for approved products, care still needs to be taken to avoid detergent or sanitizer residues on packed product. It is also important to store and use the product according to the manufacturer's instructions.

The frequency of cleaning and sanitizing should be determined for each piece of equipment. All equipment should be in a clean and sanitary condition at the start of the season.

Best Practices

Maintenance

Equipment and tools are designed and constructed to facilitate regular cleaning and maintenance.

A documented plan of preventive maintenance is followed. The plan describes:
• Areas and equipment
• Details of maintenance
• Frequency of maintenance
• Name of person responsible for ensuring maintenance is completed

Equipment is stored in a manner that minimizes contamination.

Tools

Hand held tools are suitable for the process (e.g. knives with solid blades) and cleaned before use.

In high-risk situations the use of knives is controlled, and a record is kept of used, damaged or lost knives.

Cleaning

A documented plan is followed for the cleaning of equipment, and any tools that come in contact with the produce. The plan describes:
• Areas and items to be cleaned
• Cleaning and sanitizing products, and methods used
• Frequency of cleaning and sanitizing
• Name of the person responsible for ensuring cleaning and sanitizing is completed

Chemicals used for cleaning and sanitizing are approved for use on food contact surfaces and are used in accordance with label instructions.

Cleaning and sanitizing materials are stored safely to minimize the risk of contaminating produce.

Source: Guidelines for Fresh Produce Food Safety (2015) Fresh Produce Safety Center, Australia and New Zealand

7. Managing containers and packaging materials

Supply

A list of approved suppliers for containers and packaging, and their mode of approval (e.g. an agreed specification) is kept and reviewed annually.

Containers and packaging materials are sourced from an approved supplier, or inspected when delivered and a record is kept of the inspection.

Purchase records are kept for containers and packaging materials that may present a food safety risk describing the purchased product, name of supplier, purchase date, and batch number if applicable.

Containers and packing materials are made of substances that are non-toxic and designed and constructed to enable regular cleaning and maintenance.

Storage

Containers and packing materials are stored in a manner that minimizes contamination.

Containers used to harvest and transport produce to packing and storage facilities are handled to avoid contamination of produce from soil, manure, and physical contaminants.

Containers used for storage of waste, chemicals, or dangerous substances are clearly identified and not used for produce.

Cleaning and use

A food grade liner is used when recycled packaging cannot be effectively cleaned.

Containers and packaging materials are checked for cleanliness, foreign objects, and pest infestation. They are cleaned, rejected, or covered with a protective material where required.

Wooden bins and pallets are checked for cleanliness, foreign objects, pest infestation, and protruding nails and splinters. Where risk is identified, bins and pallets should be cleaned, repaired, rejected, or covered with a protective material.

Source: Guidelines for Fresh Produce Food Safety (2015) Fresh Produce Safety Center, Australia and New Zealand

Picture 37: How to deal with pallets and packaging containers.

Source: Guidelines for Fresh Produce Food Safety (2015) Fresh Produce Safety Center, Australia and New Zealand

8. Vehicle maintenance and hygiene

During transportation, physical, chemical, and biological contamination may occur. That is why maintaining the vehicles continuously and including them in the cleaning schedule is essential to ensure the safety of the crops.

Maintenance

Vehicles are designed to enable regular cleaning and maintenance and stored in a manner that minimizes contamination. A documented plan of preventive maintenance is followed. The plan describes:

- Areas and equipment,
- Details of maintenance,
- Frequency of maintenance,
- Name of person responsible for ensuring maintenance is completed.

Cleaning

A documented plan is followed for cleaning of vehicles. The plan describes:

- Areas and items to be cleaned,
- Cleaning and sanitizing products, and methods used,
- Frequency of cleaning and sanitizing,
- Name of the person responsible for ensuring cleaning and sanitizing is completed.

Chemicals used for cleaning and sanitizing are approved for use on food contact surfaces, and are used in accordance with label instructions. Furthermore, cleaning and sanitizing materials are stored safely to minimize the risk of contaminating produce.

Source: Guidelines for Fresh Produce Food Safety (2015) Fresh Produce Safety Center, Australia and New Zealand

9. Pest and animal control

In addition to the fact that their presence is unappealing, pests are sources of microbial hazards. For this, several measures should be taken to avoid their presence, and to control their growth.

Records

Pest control measures are monitored to ensure they are effective and a record is kept. Furthermore, a documented plan is followed to minimize the presence of pests in and around harvesting equipment, vehicles, and packing and storage areas. The plan describes:

- Location of baits and traps.
- Chemicals and methods used.
- Frequency of checking baits and traps.
- Name of the person responsible for pest management.

Exclusion

Domestic animals are excluded from areas where produce is harvested, packed, and stored.

Where possible, wildlife is excluded from areas where produce is harvested, packed, and stored.

Birds are discouraged from roosting above packing and storage areas.

Control

Chemicals used for pest control are appropriate for use in a food handling area and are used according to label instructions.

Baits and traps used for pest control are located and contained to minimize the risk of chemical contamination.

Chemicals used for pest control are not applied to edible plant parts.

Source: Guidelines for Fresh Produce Food Safety (2015) Fresh Produce Safety Center, Australia and New Zealand

10. Managing people

Personal hygiene

Hands must be washed:
• Before starting work
• After each visit to the toilet
• After blowing the nose, coughing, or sneezing into ones hands
• After eating or smoking
• After touching animals
• After handling rubbish or performing maintenance on equipment
• After any break from work

Hands must be washed with water containing *E. coli*<1 cfu/100ml and dried thoroughly with single-use paper towels.

Wounds and injuries

Cuts, minor wounds, and sores must be covered with water-proof and colored bandages and dressings, secured properly to prevent them falling off. Where wounds cannot be fully covered, the worker should be excluded from direct contact with produce, equipment, and water that contacts the produce.

First aid kits with appropriate wound coverings must be readily available and kept in a sanitary and usable condition. They should also be within their 'Use by' dates.

Gloves

Dirty gloves can be a source of microbial contamination. Disposable gloves are preferable. They must be replaced with a new pair after visiting the toilet, blowing the nose, coughing or sneezing into hands, eating, smoking, handling rubbish, or touching other contaminated surfaces. Direct contact with latex gloves can cause reactions to some workers. It is preferred to use 'latex free' disposable gloves where the option is available.

Hair

Hair and beard nets should be used to minimize the risk of physical contamination by hair.

Eating, drinking, and smoking

Eating, chewing gum, smoking, and drinking fluids other than water should not be allowed. These activities must be restricted to designated areas.

Jewelry

Jewelry can fall into produce, dirt can also collect in jewelry. Ideally no jewelry should be worn during packing, except for the plain wedding band.

Clothing

Dirty clothes can carry microbes and chemicals. Workers should wear clean outer garments that do not have loose buttons, dangling materials, or hanging attachments. In high-risk situations, workers, contractors, and visitors may be required to clean or change shoes or wear protective outer clothing. In this case, such protective shoes and outer clothing must be removed before entering the toilet.

Illness

Produce directly or indirectly contacted by workers, contractors, or visitors suffering from intestinal illness (eg gastroenteritis, Hepatitis A) is at risk of contamination with human pathogens. Workers who have suffered from diarrhea, vomiting, fever, or jaundice must not harvest produce or work in packing and storage facilities until they are fully recovered. It is important that workers inform their supervisor of any illness that could affect food safety. Recovering workers should be re-assigned other duties rather than stopped from coming to work to encourage them to report illnesses appropriately.

Training

- Role of management
- Role of workers
- The level of training
- The content and format of the training
- Written instructions and signs in appropriate work areas and facilities
- Monitoring and follow-up

Picture 38: Hand washing area.

Source: Guidelines for Fresh Produce Food Safety (2015) Fresh Produce Safety Center, Australia and New Zealand

11. Suppliers of inputs and services

Suppliers of packaging materials, chemicals, and other services must be controlled since they can be source of hazards.
Their control is highlighted in the following:
• Inputs and services that present a significant food safety risk are identified
• Specifications for these inputs and services are documented
• To ensure these specifications are met, inputs and services are either:
    -Sourced from approved suppliers that demonstrate compliance with the specification.
    - inspected/assessed against the specification and a record of inspection kept.
    - Purchase records are kept for inputs and services that may present food safety risk. Records include the name of supplier, date of purchase, and inputs or services supplied.
    - A list of suppliers and their mode of approval is kept and reviewed annually.

Source: Guidelines for Fresh Produce Food Safety (2015) Fresh Produce Safety Center, Australia and New Zealand

12. Traceability

Traceability allows product history to be verified from retail back to growing location. Achieving full traceability requires each business in the supply chain to record sufficient and accurate information on product identification. Each business should be able to trace produce one step forward and backward in the supply chain.

Growing

The location of growing sites is identified on a property map or equivalent.

A record of all harvested produce is kept, which includes:
• Business name
• Crop/variety
• Growing site
• Harvest date
• Destination

Harvested produce sent to another business for packing or further processing is clearly identified with the supplier name, and harvest or delivery date.

Packing

All packed produce sent to customers is marked with the following:
• Business name, and the physical address of the supplier/packer
• Packing date, and/or batch identification code

Distributing

A record of all distributed produce is kept, which includes:
• Name, address, and other contact details of suppliers and a description of products or inputs supplied.
• Name, address, and other contact details of customers and a description of the product supplied to them.
• Date of transaction or delivery.
• Lot identification (e.g. item number or other markings).
• Volume or quantity of product supplied or received.
• Other relevant distribution records.

Traceability information needed at different steps in the supply chain

Step	Traceability information
Growing	Input purchases, crop records
↓	
Harvest	Growing location, harvest date, destination
↓	
Packing	Receival, packing, labelling, dispatch
↓	
Distribution	Receival, lot identification, inventory, dispatch

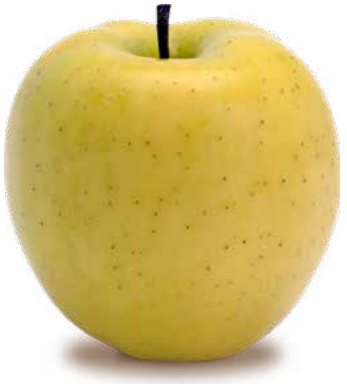
Source: Guidelines for Fresh Produce Food Safety (2015) Fresh Produce Safety Center, Australia and New Zealand

ANNEXES

Annex 1: Main varieties of apples found in Lebanon

Different apple varieties are grown in Lebanon. The Ministry of Agriculture and Non-governmental Organizations working in Lebanon advise farmers on varieties that have both high prices and high market demand. Still Lebanese farmers cut scions from other apples' orchards to graft their own trees without understanding the concept of variety mutations and diseases transfer from these practices. For that reason farmers suffer from heterogeneous production especially in terms of fruit size and color within the same variety. Extension engineers should guide farmers to plant true to type varieties bought from certified nurseries. Farmers should learn about the specifications of every variety in order to know what to expect when their trees start to produce apples.

Table 1.1: List of apple varieties and their specifications:



Source: (Pacific northwest fruit Packer, shipper and marketer, 2005)

1. Golden Delicious:

• Susceptible to mildew
• Moderately resistant to scab and fire-blight
• High chilling requirement and does not store well
• Fruit shape: Medium, conical
• Golden when mature sometimes with a slight blush, and it bruises easily
• Creamy yellow flesh, excellent flavor, and sweet and juicy
• Mid blossom season and ripens late September to October

Source: (Apple varieties, 2005)

Source: (Pacific northwest fruit Packer, shipper and marketer, 2005)

2. Red Delicious, Starking:

• Susceptible to scab and woolly aphid, some resistance to powdery mildew
• Resistant to fire-blight
• High chilling requirement
• Medium, tall conical fruit with five crowns
• Striped red on 25–50 percent of surface
• Firm, crisp, and juicy
• Mid blossom season and ripens in October

Source: (Apple varieties, 2005)

Source: (letsgrowapple, 2015)

3. Scarlet Spur:

• This variety comes from the Starking family
• Semi dwarf variety, growth is moderate to weak
• Mid-early bloom
• Fruit size 70-85mm
• Spur type tree
• Pollinated by Granny Smith, Golden Delicious, and Gala
• Full intense blushed color at harvest
• Good storage quality
• Dark red in color with white flesh that is crispy and juicy
• The shape of the fruit is not completely uniform: it may vary from oblong to slightly flat

Source: (letsgrowapple, 2015)

Source: (Nakad, 2005)

4. Early Red One

• This variety descends from the Starking family: Red Delicious
• This variety cannot be stored for a long time
• Early variety and a heavy producer
• Elongated shaped fruit with a beautiful red color

Source: (Nakad, 2005)

Source: (Nakad, 2005)

5. Red Chief:

• This variety comes from the Starking family
• Widely planted in Europe
• High in production
• This variety can withstand cold storage for long times
• Dark red in color

Source: (Nakad, 2005)

Source: (letsgrowapple, 2015)

6. Super Chief:

• Mutation of Red Chief
• Mid-Early Bloom
• Fruit Size 65-85 mm
• Typical spur type tree
• It also helps in pollination
• Less vigor than Red Chief
• Pollinated by Granny Smith, Gala, Golden Delicious, and Fuji
• Elongated fruit with prominent calyx lobes
• Intense red color with stripes
• Fruit flesh is white, firm, crispy and juicy
• Good storage quality

Source: (letsgrowapple, 2015)

Source: (Nakad, 2005)

7. Top Red:

• This variety comes from the Starking family
• This variety can withstand cold storage for long times
• Big round fruit
• Dark red in color
• Taste is lightly acidic

Source: (Nakad, 2005)

Source: (Nakad, 2005)

8. Ace:

• This variety comes from the Starking family
• High in production
• This variety can withstand cold storage for long times
• Dark red in color
• Special taste with a bit of acidity

Source: (Nakad, 2005)

Source: (Pacific northwest fruit Packer, shipper and marketer, 2005)

9. Fuji:

• From Japanese origin, it is a hybrid between Golden Delicious, and Red Delicious
• Resistant to scab, some resistance to powdery mildew but susceptible to fire blight
• Medium chilling requirement up to 575 hours
• Blossom mid to late and ripens October to early November
• Fruit shape is round, flat, and conical,
• Average in size
• Pink-red striped on 50–80 percent of surface, it can look dull
• Yellowish flesh, firm, crisp, and juicy with lots of flavor
• Good for storage (up to 6 months),
• Susceptible to scalds

Source: (NSW department of primary industries, 2005)

Source: (Nakad, 2005)

Source: (Pacific northwest fruit Packer, shipper and marketer, 2005)

10. Gala (Red Strain = Royal Gala):

• A result from a mutation
• Susceptible to scab, mildew, & fire blight
• Mid-season blossom
• Needs care with thinning
• Very early variety
• Medium chilling requirement (600 hours)
• Fruit is conical in shape, average in size
• Orange-red on 50 percent of surface color
• Very juicy with good taste
• Ripens in September
• Keeps well when stored; no bitter pit, scald, or breakdown

Source: (NSW department of primary industries, 2005)

11. Granny Smith:

• An Australian variety
• Susceptible to fire blight, & Mildew
• Mid blossom season and ripens late October to November
• Medium to high chilling requirement
• Can be stored for a long time, but susceptible to scald
• Heavy producer
• It ripens late
• Fruit is round in shape, average in size, and green in color
• Solid in texture
• Taste is acidic and contains a small amount of sugar

Source: (NSW department of primary industries, 2005)

Annex 2: Main rootstocks for apples

All apple trees sold commercially are grafted trees. Some trees are grafted on regular apple seeds and others are grafted on commercial rootstocks with special characteristics related to tree height, density and resistances to some soil diseases. Extension engineers should promote awareness to farmers about not planting apple trees grafted on regular seeds, as they will face losses in the future related to production and quality (shape, size, and color of the fruit).

Table 2.1: Name of apple commercial rootstocks and their specifications.

Name of rootstock	Tree Height	Spacing	Density / du
MM 25	6m	6 * 6	28
MM 111	5.5 m	4.5 * 3.5	64
MM 106	5m	4 * 3.5	71
M 7	4.5 m	3.5 * 3	95
M 26	3.5 m	3 * 2.5	123
M 9	2.5 to 3m	2.5 * 2	222

Source: (Nakad, 2005)

Table 2.2: Name of apple commercial rootstocks and their resistances.

Name of rootstock	High PH	Cold Weather	Root Rot	Wooly Apple Aphid	Fire Blight	Other
MM 25	Tolerant	Tolerant	Resistant	Low	Low	Drought Resistant
MM 111	Low	Low	Resistant	Resistant	Medium	Drought Resistant
MM 106	Variable	Low	Low	Resistant	Low	Excellent root anchorage
M 7	Tolerant	Tolerant	Resistant	Resistant	Resistant	Most tolerant to wet soil
M 26	Low	Low	Medium	Variable	Low	Require supporting
M 9	Variable	Variable	Medium	Low	Low	Require supporting

Source: (Nakad, 2005)

Table 2.3: Some other fruit characteristics of some apple cultivars / rootstock.

Cultivar/Rootstock	Fruit weight (g)	Fruit diameter (mm)	Fruit length (mm)	Seed number
Fuji/M8	198.75	78.5	66.05	9.15
Galaxy Gala/M9	147.45	70.85	58.4	6.6
Granny Smith/M9	196.75	78.4	68.5	9.15
Early Red One/MM106	164.5	72.45	62.55	8
Red Chief/MM106	173.8	73.95	63.2	7.15
Scarlet Spur/MM106	156.2	70.75	61.7	8.35
Super Chief/MM106	153.2	72	61.2	7.4

Source: (Bozbuğa and Pırlak, 2012)

Annex 3: Pest and disease management

Time/growth stage	List of Integrated Pest and Disease Management tasks
Dormant period	**Measure and check:** • Overwintering populations of rust mite behind growing shoot buds. • Red spider mite winter eggs around spurs. • Aphid eggs on shoots. Apply winter oil spray if high populations of scale insects on bark, while trees are fully dormant. **During winter pruning:** • Remove cankered branches, wood scab and mildew infected (silvered) shoots, root stock sucker growths (which may harbor bugs eggs). • Protect pruning wounds with suitable canker paint. Check leaf litter that is left in the orchard by the end of February as this may be a source of scab inoculum.
Just pre bud-swell	Consider a pre-bud-burst spray of a copper fungicide, especially where canker and scab were bad in the previous season. This may give some control of overwintering scab and protect against Nectria canker.
Bud-swell	Start program of fungicide sprays for scab control quickly.
Bud-burst	Monitor populations of apple blossom weevil adults at edges of orchards. Apply a spray of chlorpyrifos in good conditions. Continue sprays for scab to maintain good protection at this sensitive stage.

Green tip stage of apple bloom.
(Clark, 2000a)

Green cluster

Monitor numbers of rust mites on outer rosette leaves. If threshold (5 mites per outer leaf) is exceeded, apply acaricide, or include Sulphur at rate of 300 grams / 200 L in next 3 spray rounds.

Conduct pre-blossom pest assessment for aphids, caterpillars, bugs, rust mite and other minor pests. Apply pre-blossom insecticide spray if necessary (Indoxycarb).

Start mildew spray program like myclobutanil, kresoxim-methyl, pyraclostrobin + boscalid and sulphur.

Continue sprays for scab to maintain good protection at this sensitive stage.

Tight cluster stage of apple bloom.
(Clark, 2000b)

Pink bud

Check truss leaves for scab until early June.

Measure primary mildewed flower trusses. >2 percent indicates a problem, >10 percent a severe problem. Use mildew fungicide.

Apple pink bud stage.
(Clark, 2000c)

First flower

Continue spray program for scab and mildew as necessary. Apply first spray for blossom wilt (Monilinia). Repeat 7 days later. Bellis (boscalid + pyraclostrobin) or Switch (cyprodinil + fludioxonil).

Full bloom

Continue spray program for scab and mildew as necessary, but try to avoid spraying fungicides at this critical time if possible.

Photo by Jack Kelly Clark.
(Clark, 2000d)

Late blossom

Continue spray program for scab and mildew as necessary

Conduct late blossom pest assessment for aphids, winter moth, red spider mite, rust mite and capsid, and capped blossoms due to apple blossom weevil.

End of blossom, Apple petal fall stage.

Continue spray program for scab and mildew as necessary.
Measure primary mildewed vegetative terminal buds. >2 percent indicates a problem, >10 percent a severe problem. Use good mildew fungicide, decrease spray interval and increase spray volume if a problem.

Check for signs of wilting, dying blossoms due to blossom wilt.
Check for early signs of collar rot (Phytophthora) in older orchards on susceptible rootstocks. Early detection means the tree can be saved. Irrigate with mancozeb + metalaxyl at a rate of 400 g / 200 L water.
Apply post blossom insecticide spray if required for aphids or other pests.
Apply acaricide spray for rust mite or fruit tree red spider mite if necessary. Spray acetamiprid at a rate of 100 g / 200 L water.
If required, apply second spray of indoxacarb for summer fruit caterpillars.
(Clark, 2000e)

Early June

Check orchard thoroughly for signs of scab on leaves or fruitlets. Continue sprays as necessary if scab is present, or if the weather is very wet or if scab problems occurred last year.

Monitor mildew in shoots regularly every two weeks. Ideally before each spray round.

In orchards where canker (Nectria) is a problem, apply a spray, example Captan (ethanethiol) or Folicur (tebuconazole), to protect leaf scars from canker during summer leaf fall.

Conduct early June pest assessment for aphids, moth, red spider mite, rust mite. Insecticidal treatment should be considered if the pests are detected.

Continue weekly monitoring for codling moths spray diflubenzuron, chlorpyrifos or indoxacarb.

Late June

Continue monitoring mildew in shoots regularly, at least every two weeks before each spray round. Continue mildew sprays until the extension growth has ceased.

Continue sprays for scab only if necessary.

Look for signs of die back on extension growth caused by canker. Cut out and burn.

Conduct late June pest assessment for aphids, codling moths, red spider mite, and rust mite. Apply control treatments as necessary.

Continue weekly monitoring for codling moths spray diflubenzuron, chlorpyrifos, or indoxacarb.

July-August	Continue monitoring mildew in shoots regularly, at least every 15 days, ideally before each spray round. Continue mildew sprays until the extension growth has ceased. Continue sprays for scab only if necessary In orchards where a risk of Phytophthora rot has been determined, and where post-harvest drenches will not be used, apply sprays of Captan at 2-3 week intervals to protect fruit against infection. Conduct late July-mid August pest assessment for aphids, red spider mite and rust mite. Apply control treatments as necessary.

Source: Integrated pest and disease management - apple best practice guide.

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