Factors affecting post-harvest management of apples:

a guide to optimising quality

**Robert Nissen, Sally Bound,
Rajendra Adhikari and Ian Cover**

This book was produced through a joint partnership by the Tasmanian Institute of Agriculture, Fruit Growers Tasmania, and Department of Agriculture and Water Resources.

First published 2018.

National Library of Australia Cataloguing-in-Publication entry

Authors: Robert Nissen, Sally Bound, Rajendra Adhikari and Ian Cover

Title: Factors affecting postharvest management of apples: a guide to optimising quality

ISBN: 978-1-925646-16-0

This project output has been funded by the Department of Agriculture and Water Resources.

Contents

Contents (cont.)

Contents (cont.)

Introduction

Historically the Australian apple industry has exported to over 30 countries, but following a slump in apple exports due to loss of several markets in the mid 1970's, exports have been growing steadily in recent years. Information provided in this manual is to assist and improve the knowledge of Australian apple growers who are considering sending their fruit to export markets. The aim of the manual is to assist growers to achieve the highest possible fruit quality to optimise the eating experience for consumers of Australian apples and ensure continued market access.

Fruit quality can be lost at any stage in the supply chain, including during harvesting, handling, storage and transport. So to maintain quality, attention to detail is important at all levels in the supply chain.

Engineering aspects of constructing and fitting out cold rooms and storage facilities are not covered in this guide. This is due to the wide array of storage facilities in terms of construction, age, coolers, scrubbers and equipment to control the atmosphere used in the storage facilities. Therefore, we assume that apple growers and exporters meet the requirements to cool fruit, maintain temperatures and controlled atmosphere conditions accurately as per the market access protocols for each country they wish to service.

Quality assurance systems are increasingly important to allow market access, however handling and storage conditions appropriate for each cultivar require careful monitoring. It is critically important to maintain strategies to preserve quality of harvested apples by reducing respiration and ethylene production during the postharvest phase. Good postharvest management maintains quality by reducing the ripening and metabolic (biochemical) processes that result in unwanted changes in colour, texture, flavour, composition and nutritional status. In addition, good postharvest practices also reduce water loss and gas production which results in shrivelling and shrinkage, softening, and change in appearance (the good; the not so good; the down-right ugly).

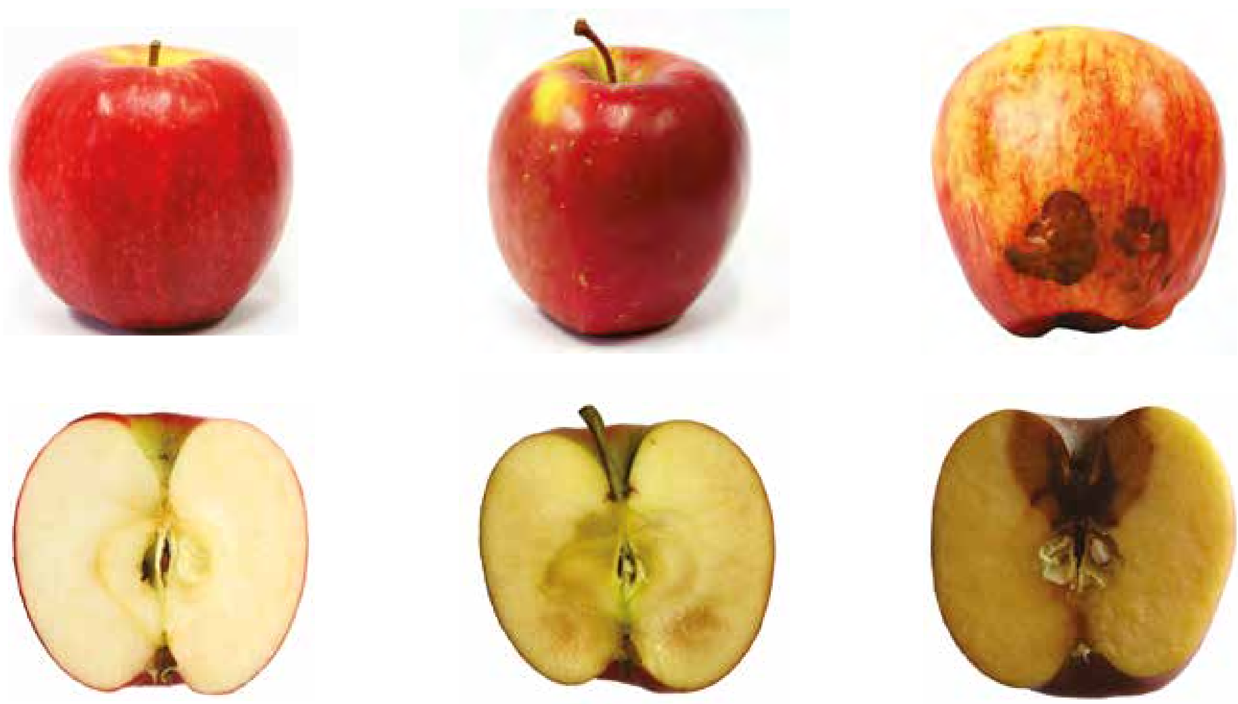


Figure 1. *Variation in fruit quality. From left to right: the good; the not so good, and the down-right ugly.*

Section 1: General

Customer requirements

There are a large number of apple cultivars available around the world. However, several cultivars dominate the global supply and production: 'Fuji', 'Golden Delicious', 'Delicious', 'Granny Smith' and 'Royal Gala' to name a few. Due to significant competition from many countries, fruit need to be of optimum quality and appearance in size, shape and colour, with freedom from blemishes, disorders and diseases. However, price and delivery timing (seasonal, and ability to deliver on time) are also key factors. These factors have to be considered when selecting cultivars, maturity levels, harvest time, storage conditions and packaging for your target market. Therefore your customer requirements will have a substantial impact on your postharvest practices.

Consumer requirements

Consumer behaviour and purchasing habits have undergone considerable change in the past decade. Consumer purchases are influenced by economic, cultural, social and physiological factors. Traditionally consumers were concerned with price and quality, but consumer behaviour has shifted and focus is now on freshness, nutrition, health value, quality, price, taste and the production systems used. Therefore understanding wants and needs of consumers are the drivers that impact your farming enterprise, economic and environmental sustainability and ultimately your postharvest practices.

Good agricultural practice

The proliferation of good agricultural practice (GAP), food safety and quality assurance guidelines in Australia and around the globe continue to appear. The number of different systems that farming enterprises are required to comply with is now becoming a real challenge, and in some instances a burden, time wise and financially. The associated audits, compliance costs, and inconsistencies in the way GAP, food safety and quality systems are being implemented are major concerns to farming enterprises and present significant challenges to growers. Presented here are some guidelines to assist growers and packers to assess risks occurring during production, harvesting, transporting, sorting, grading, packing, storage and dispatch of apples to customers and consumers.

Food safety is part of your GAP system. This also includes field management and postharvest practices. In the 1960's, the concept of hazard analysis and critical control points (HACCP) was conceived. This was developed as a systematic preventative approach to food safety by eliminating potential biological, chemical and physical hazards in the production and supply chain processes.

Today, HACCP principles are included in the International Organisation for Standardisation (ISO) 22000 Food Safety Management System (FSMS) 2005 which is a complete food safety and quality management system incorporating Goods Manufacturing Practices (GMP), Standard Operating Procedure (SOP) and Sanitation Standard Operating Procedure (SSOP) leading to International Organisation for Standardisation (ISO) 9000 for Quality Management.

There are a number of different ISO's and some relevant standards are:

- ISO 14000 Environmental management
- ISO 22000 Food safety management
- ISO 31000 Risk management
- ISO 26000 Social responsibility
- ISO 50001 Energy management.

Farming enterprises are responsible for their own produce safety. It is not uncommon for growers to contract harvesters to pick, packers to pack or processors to process the crop. However, responsibility for your produce still rests with you the grower, unless the harvester, packer or processor purchases your crop through a legal bill of sale. This is based on the legal premise that the produce is not contaminated and is fit for human consumption.

Product quality depends upon implementation of GAP for the growing and management as well as acceptable protocols for harvesting, storage and, where appropriate, processing of farm products.

Harvesting must conform to regulations relating to pre-harvest intervals for agrochemicals and withholding periods.

Good practices related to harvest and on-farm processing and storage of food products will include following relevant pre-harvest intervals and withholding periods; provision for clean and safe handling for on-farm processing of products; and the use of recommended detergents and clean water for washing produce.
Food produce should be stored under appropriate conditions of temperature and humidity in a space specifically designed and reserved for that purpose. Whilst the storage of food products is under hygienic conditions, further considerations should be given to the appropriate environmental conditions. The packaging of food produce for transport from the farm should be in clean and appropriate containers.

Specific attention should be given to the supervision and training of staff in produce handling and proper maintenance of equipment should be undertaken.

Section 2: Apples grown in Australia

Apple production regions in Australia

Apples are grown in six states of Australia. Production regions extend from the most northern region, Stanthorpe in Queensland, to the most southern region, the Huon Valley in Tasmania and from the most eastern region Bilpin in New South Wales to the western region of Pickering Brook in Western Australia - see Figure 2 below.

Figure 2. *Australian apple production regions.*

Key to growing regions:

Tasmania
1. North West (Spreyton)
2. Tamar Valley
3. Huon Valley

Victoria
4. Harcourt
5. Bacchus Marsh
6. Mornington Peninsula
7. Yarra Valley
8. Gippsland
9. Goulburn Valley
10. North East

South Australia
11. Adelaide Hills

Western Australia
12. Perth Hills
13. Pickering Brook
14. Donnybrook
15. Manjimup

New South Wales
16. Orange
17. Bilpin
18. Batlow

Queensland
19. Stanthorpe

Australian apple export cultivars

Many cultivars are grown in Australia, from the older heritage cultivars through to the newer club cultivars now being made available. However only a small selection of these are exported. The wide range of production practices and environmental conditions in the diverse production regions within Australia lead to variations in size, shape, colour and appearance within each cultivar. The cultivars most commonly exported are shown in Figure 3.

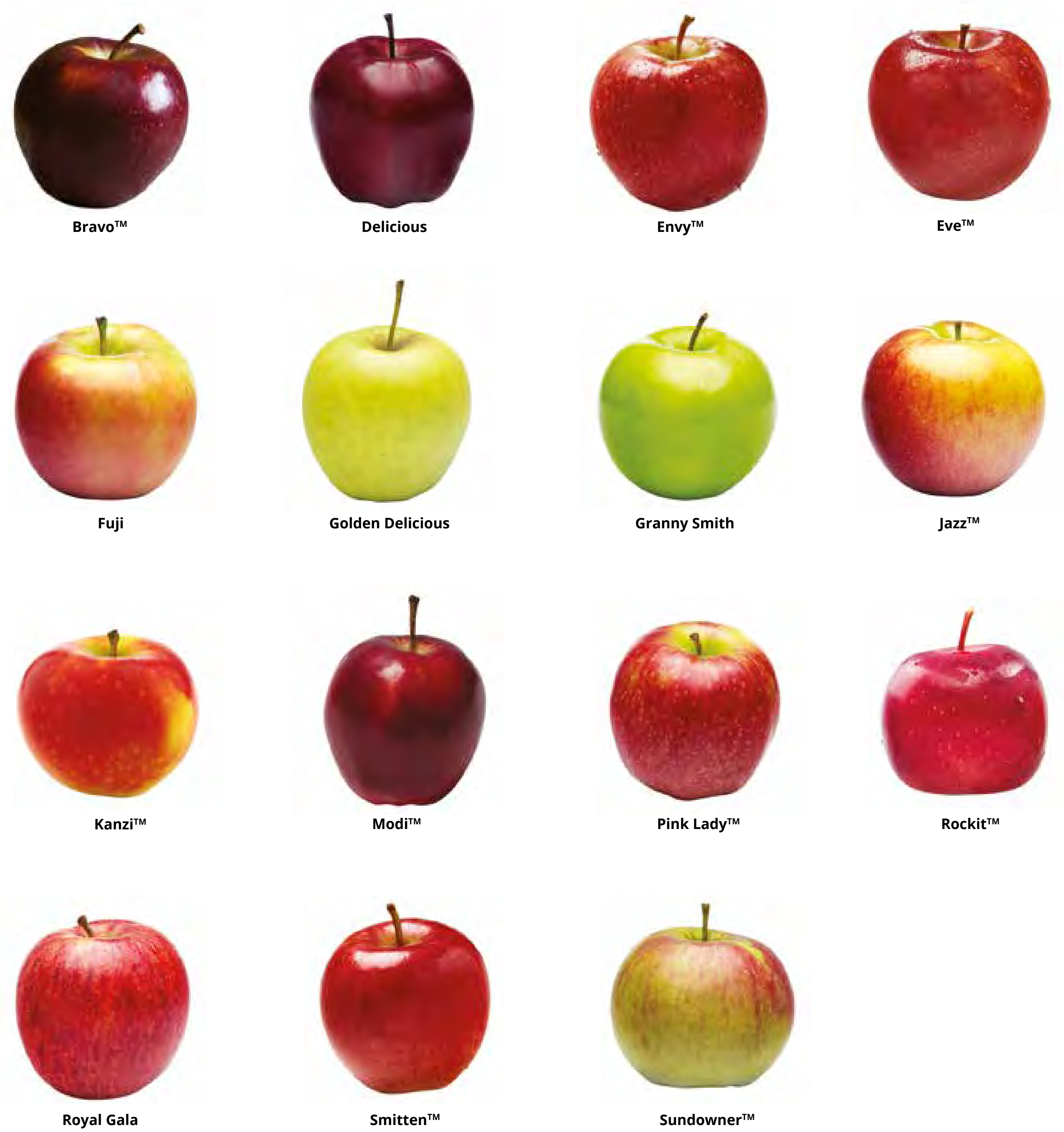


Figure 3. *Apple cultivars exported from Australia. Source, Images shown above are from a variety of sources: Horticulture Innovation Australia Pty Ltd (Hort Innovation), Montague, APAL, and Robert Nissen, TIA University of Tasmania.*

Australian apple cultivar harvest and availability periods

Australian apples are generally harvested from late summer (mid-January) to late autumn (mid-May). There is a large variation in cultivars from the time of flower petal fall to harvest. In Australia, the production period (flowering to harvest) varies from approximately 105-205 days depending upon cultivar, elevation, longitude and latitude and growing region. Indicated below are the harvest times and export availability periods for some Australian apple cultivars.

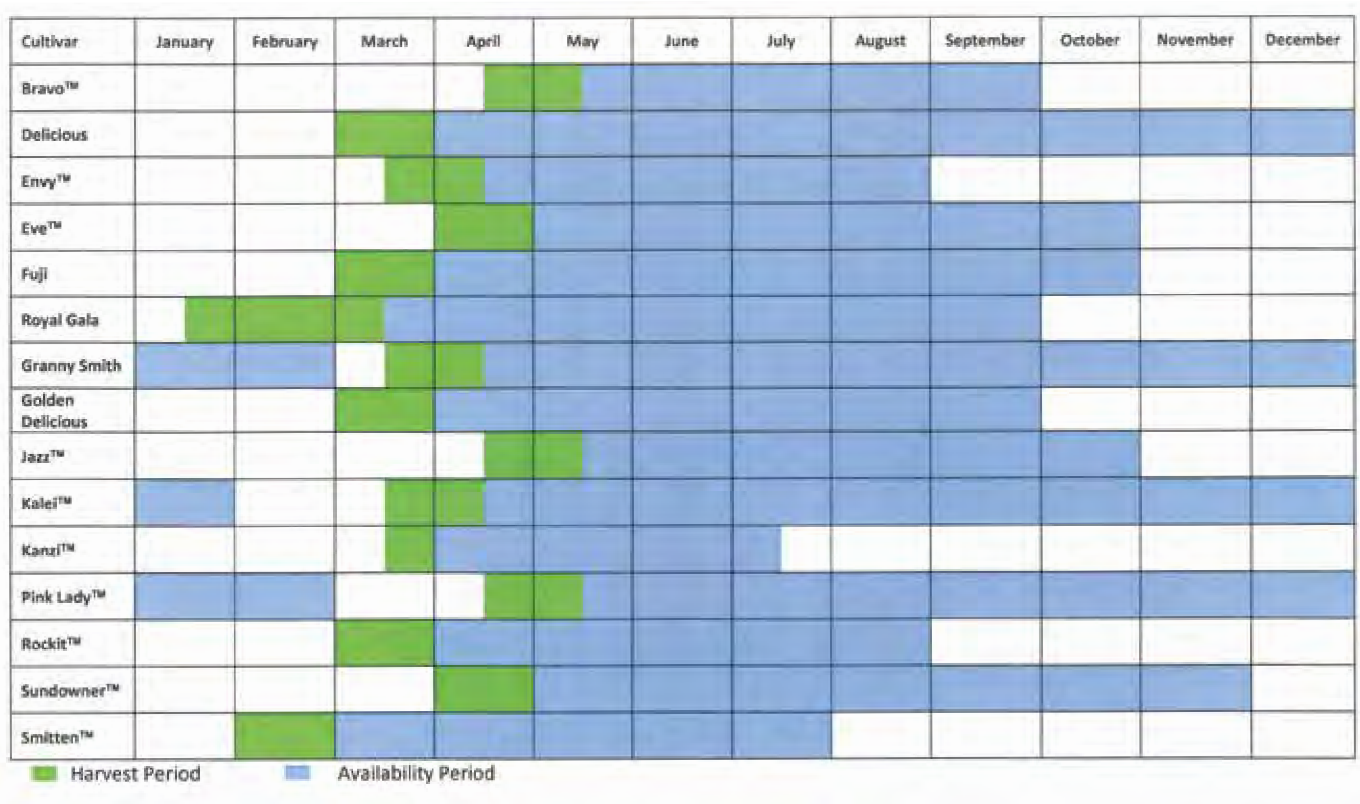


Figure 4. *Harvest and availability periods for apple cultivars grown in Australia for export.*

Anatomy of the apple

The apple is a pome fruit in which the edible flesh arises from the ripened ovary and surrounding swollen receptacle. Botanically it is classified as an accessory or false fruit.

The fleshy edible portion of the apple fruit surrounding the ovary is called the hypanthium (Figure 5). In addition to consuming the hypanthium of the apple you normally consume some of the outer flesh of the ovary as well. The inner core that contains the seeds is not normally eaten.

The hypanthium is formed from the fusion of the sepal and petal bases with the ovary wall and the structure of the fruit affects the ripening process. The seeds of the apple are contained within the core and remnants of the calyx and stamens are visible at the base of the apple (Figure 5).

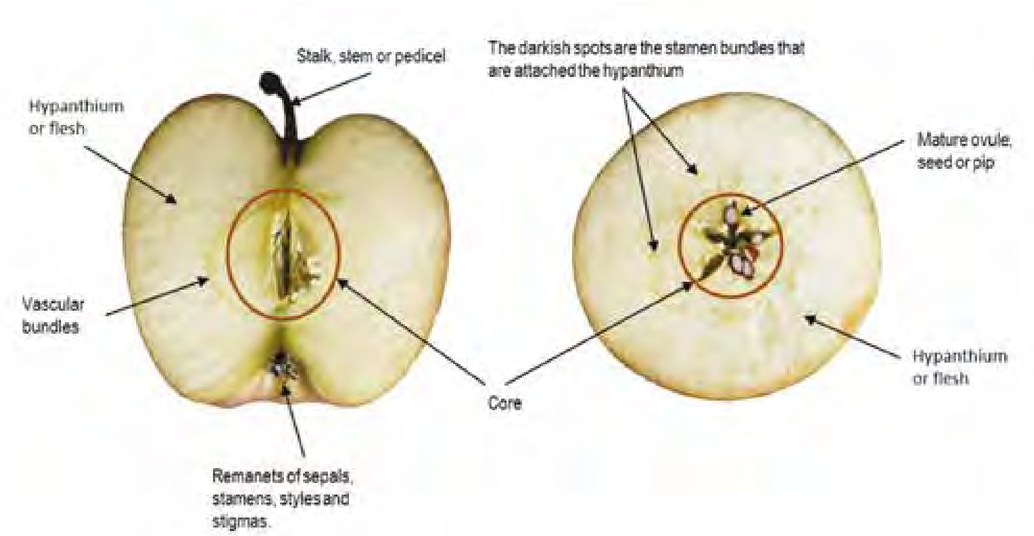


Figure 5. *Anatomy of an apple (longitudinal and cross-section views).*

The amount of anthocyanin (red colour) contained in the skin of the apple is dependent on the cultivar and its genetic makeup. Apples are classified as climacteric fruit due to an increase in their rate of respiration during the ripening phase compared to other non-climacteric fruit (Figure 6). In addition, early harvest cultivars tend to have slightly less flavour, and a higher risk of bitter pit and scald.

The ripening processes of apples

Changes that occur during the ripening process in apples include:

- an increase in respiration
- production of ethylene
- change in colour and appearance
- development of volatiles associated with flavour
- flesh softening

During the postharvest stage, ripening is the phase where the apple fruit changes from the physiologically mature state to the senescence state. Senescence is the term used to describe aging and death of plant tissue. During the ripening or developmental phase, substantial changes in chemical processes (biochemical) and physical characteristics occur in apples.

Fruit are classified as either climacteric or non-climacteric. Climacteric fruits undergo a rapid ripening phase (Figure 6), in which they soften, colour, and develop desirable flavour and aroma in contrast to a non-climacteric fruit which matures slowly while attached to the parent plant and is usually picked when sweet and ready to eat.

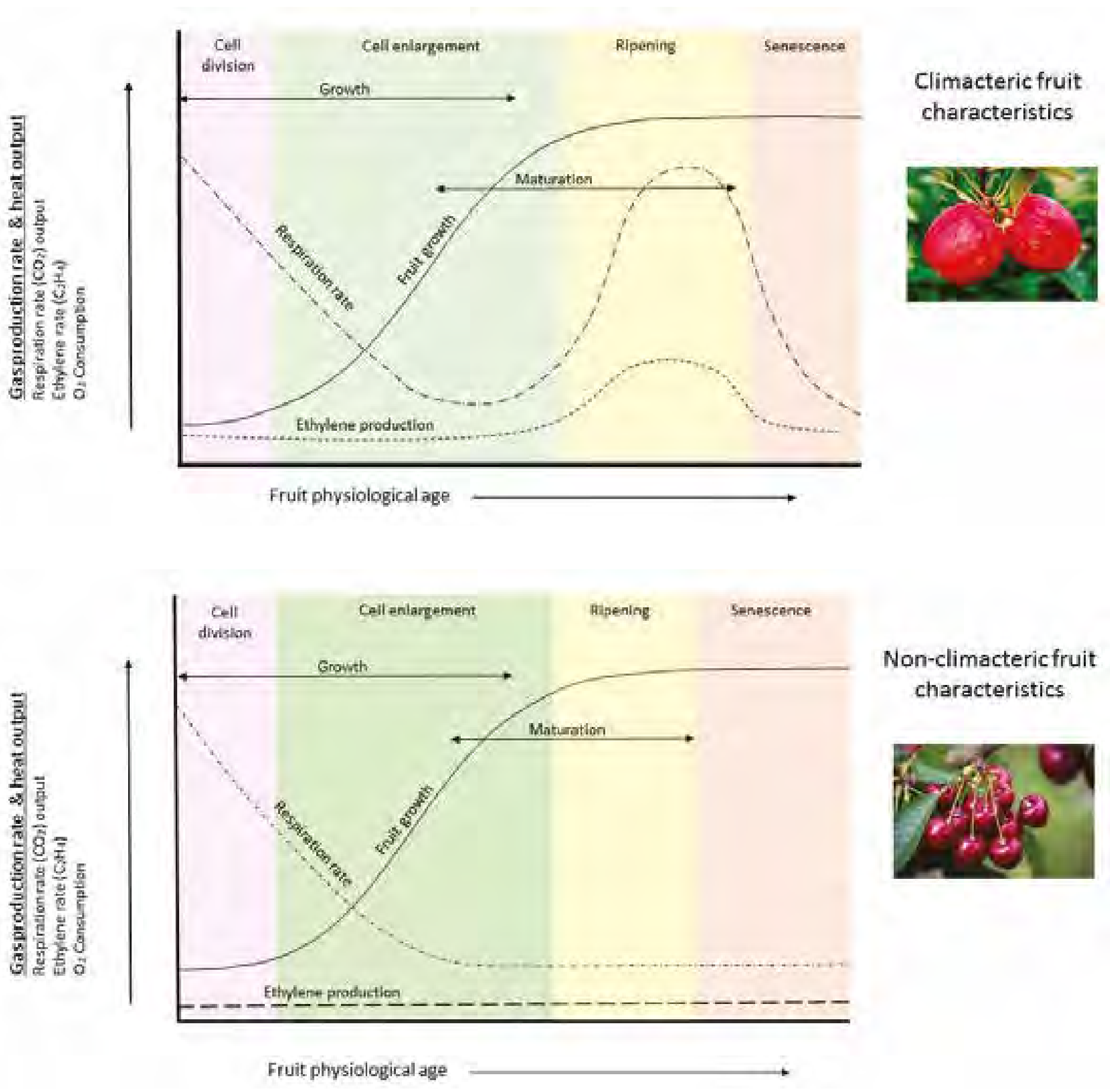


Figure 6. *Fruit physiological stages and gas production rates comparison of climacteric and non-climacteric fruit.*

At the end of the maturation period and in the early stages of the ripening process, an extremely small amount of ethylene is produced by the core of the apple. This release of ethylene is a signal for an increase in skin respiration rate; apple skin tissue has a significantly higher rate of respiration than the flesh. The flavour development of apples (flavour volatiles) is dependent upon ethylene and occurs in cells with higher rates of respiration.

Understanding fruit quality

High fruit quality is vital to ensuring acceptance of fruit, not only in the export market, but also by consumers. Quality is a combination of physical and chemical properties and quality attributes can be divided into three classes: external, internal and hidden. The first assessment of quality is usually visual, being determined by size, shape, skin colour and freedom from blemishes. Textural quality factors include firmness, crispness, juiciness and mealiness, while flavour or eating quality depends on sugar content, acidity, astringency and aroma. Hidden quality attributes include wholesomeness, nutritional value and food safety.

The definition of quality is dependent on where you are in the supply chain:

- producers want a product that will maximise return on investment and profitability, and hence desire high yields and good appearance.
- wholesale and retail marketers are after visual appeal, firmness and good shelf-life.
- consumers judge quality on the basis of appearance (including "freshness") and firmness at time of initial purchase, but subsequent purchases are dependent on flavour and texture.

Deficiencies in quality attributes can render a product valueless. In apples, immaturity, over-ripeness, poor grading (mixed colour/sizes), and marks and blemishes usually lead to rejection by retailers and wholesalers.

Quality means different things at different levels of the supply chain. External attributes related to appearance (size, shape, colour, freedom from defects) play a major role in initial purchasing decisions. The internal (flavour, texture) and hidden attributes are what bring customers back.

Quality attributes

As noted earlier, quality is a combination of external, internal and hidden attributes. Quality assessments can be objective (measurable) or subjective (relying on individual judgement).

1. Fruit size

Fruit size is determined by the number and size of cells in the fruit flesh, cell number is determined within the first 4-6 weeks of fruit development. After the cell division phase the degree of expansion of fruit cells and intercellular spaces determines the final fruit size.

For optimal quality and storage, the aim is to maximise cell number in the fruit while minimising cell size, as fruit with larger cells are less firm and tend to be more prone to storage disorders than fruit with smaller cells.

Final fruit size is a function of the interaction of genetics, environmental conditions and cultural practices, but anything that limits carbohydrate availability, water or nutrient supply during the growth of the apple will impact the number of cells within the fruit as well as cell size, thus potentially reducing final fruit size.

Seed number has a direct influence on fruit size, and the higher the number of seeds the larger the fruit. As seed number is directly related to pollination, it is important to ensure adequate compatible pollinisers in the orchard - the polliniser should be in full bloom when the main cultivar is at the King bloom stage.

Spur age affects fruit size, with older spurs producing smaller fruit; but the impact of spur age can be somewhat ameliorated with good light exposure and strong buds. Optimal light is achieved through tree training and pruning. Recent studies by Australian and New Zealand researchers have shown that buds on short terminal shoots produce the largest fruit, closely followed by spurs. Laterals on first year wood produce the smallest fruit.

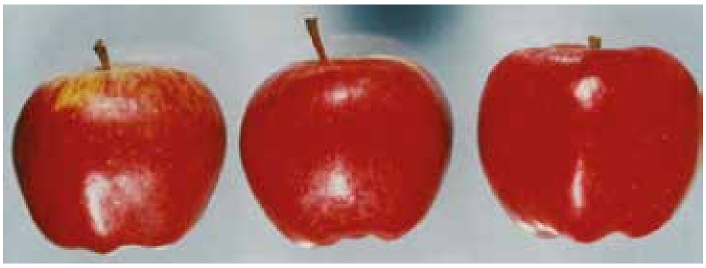
2. Shape

Each cultivar has a characteristic fruit shape, but this can be influenced by multiple factors including rootstock, crop density and position of the fruitlet within the cluster. Temperature also plays a role in fruit shape, with cool temperatures during the cell division and early developmental growth phase resulting in elongated fruit, while warmer temperatures tend to produce oblate flatter fruit.

Application of synthetic hormones will affect fruit shape. Gibberellins (GA) promote cell division and elongation in apples and mixtures of GA_{4+7} and BA (eg. Cytolin®, Abbott Laboratories) are used to improve fruit typiness in 'Delicious' and increase fruit size in cultivars such as 'Gala' (Figure 7).

Localised application of GA can induce asymmetric growth of apples as a result of tissue enlargement. Fruit symmetry is also affected by seed development – fruit with uneven seed distribution tend to be lopsided (Figure 8).

(a)



(b)

Figure 7. *Manipulating fruit shape with plant bio-regulators*
(a) normal shape of 'Delicious' apple
(b) development of calyx lobes to improve fruit typiness in 'Delicious' following application of Cytolin®

Figure 8. *Effect of seed distribution on fruit symmetry, empty locules are associated with the short side of the fruit.*

3. Colour

Colour is divided into two components, background colour and red colour (in red cultivars). Background colour is used as one of the maturity indices and is a subjective estimate of the change from mainly green colour on unripe apples to yellow tones on ripe apples; however with the recent development of the DA meter we will be able to measure background colour objectively in the future.

Red colour is the result of accumulation of the red pigment anthocyanin in the fruit skin. The extent and intensity of anthocyanin development is affected by nutrition, orchard management factors and by environmental conditions. Anthocyanin synthesis is strongly light dependent, with both intensity and quality of light being important – blue-violet (BV) and ultraviolet (UV) light are the most effective at inducing colour development. Low temperatures increase anthocyanin concentration while high temperatures reduce concentration. Excess nitrogen is associated with poor colour, as is tree vigour – although this is the result of an indirect effect caused by shading. Managing the canopy to reduce shade will have a major impact on fruit colour – fruit colour best if they are exposed to more than 70% of full sunlight; those receiving less than 40% full sunlight do not colour well.

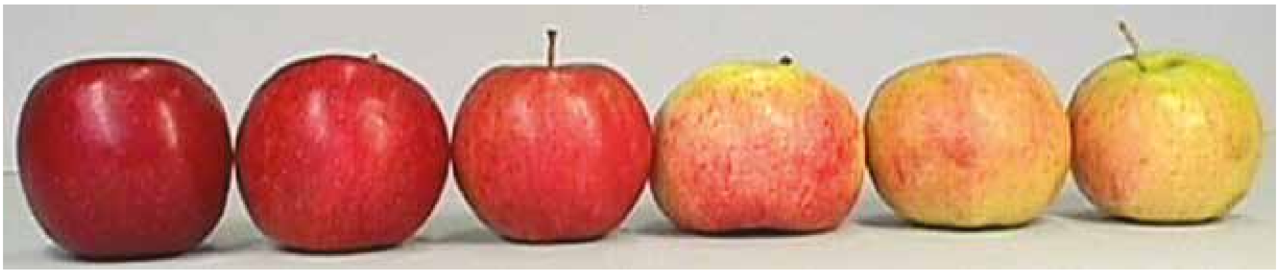


Figure 9. *Sundowner showing variation in red colour.*

Red colour is not a reliable indicator of maturity, but is normally taken as a quality factor unlikely to change substantially as fruit progresses through the last stages of development. Fruit is picked either when the red colour meets a grade standard, as for 'Delicious', or when red colour is sufficient and background colour indicates that an appropriate level of maturity has been reached. Poorly coloured fruit is usually downgraded from fresh market to processing grade or left on the tree. However fruit left on the tree can harbour pests and disease, so to reduce pest/disease loads in the orchard, all fruit should be removed from the trees and orchard at or shortly after harvest.

4. Skin finish

Skin finish problems can be divided into blemishes or skin damage. A blemish is superficial disfigurement of the skin that is not likely to affect keeping quality, and includes russet and healed injuries caused by limb rub, insect damage, abrasions and scratches. Skin damage is any unhealed physical injury to the apple surface, including bruising and injuries that leave the skin broken such as stem punctures or hail damage.

Russet

Russet is one of the major problems with skin finish; it develops on fruit that suffers damage to the cuticle early in the growing season. A layer of cork cambium develops and pushes outwards to replace the cuticle as the outer protective layer of the fruit; cork cambium is rough in texture giving the fruit the characteristic russeted scabby appearance. The amount of russet depends on the degree of injury. Developing fruit are most sensitive to damage from as early as the pink bud stage through to 6-8 weeks after full bloom. However, fruitlet exposure to further russeting events can occur later in the season, subjecting fruit to further damage.

Russet does not affect taste or other quality parameters, but reduces the visual appeal of the fruit and hence has a serious detrimental effect on market value. Russet is a major problem in susceptible cultivars, and can result in more than 50% of otherwise exportable fruit being rejected.

Fruit skin russet is caused by an extensive range of factors including prolonged wet weather, cold temperatures, frost, high humidity, slow drying conditions, poor drainage, and exposure. Worthy of note is that, while some chemicals and surfactants are known to cause russet, any chemical spray applied under the wrong weather conditions during the critical fruit development period is capable of causing russet. Tree health is important in minimising russet. Although it is not possible to completely alleviate the damaging effects of russet as many of the contributing factors cannot be controlled or prevented, it is possible to manipulate many cultural factors to reduce the incidence of russet.

Figure 10. *Russet on developing fruit.*

Sunburn

Sunburn is the result of damage to the sun-exposed surface layers of the fruit. Apple fruit have limited cooling capacity via transpiration from the skin, unlike leaves. Sunburn is most likely to occur when the air temperature (in the shade) is above 30°C and fruit surface temperatures are above 45°C. It is important to note that leaf temperatures are approximately 5-10°C above the ambient air temperature, with exposed fruit temperatures even higher.

Three types of fruit sunburn have been identified in apples:

1. Sunburn necrosis
2. Sunburn browning
3. Bleaching or photo-oxidative sunburn

Figure 11. *Sunburn in apples.*
Source Department of Primary Industries, Farm Services Victoria.

Further information on sunburn is available in the following publication Sun Protection for Fruit: a practical manual for preventing sunburn on fruit, available from:
http://www.hin.com.au/__data/assets/pdf_file/0018/17730/Sun-Protection-Manual-for-Fruit.pdf

Bruising

Bruising is one of the major defects affecting apple quality at the retail level. Bruises are seen as depressed or flat areas of the surface that yield readily to slight pressure, and are usually accompanied by discoloured, soft and/or disintegrated flesh, normally brown in colour, but not decayed. They are a result of impact and/or compression of the fruit, and can occur either pre-harvest or during harvest, post-harvest handling, transporting, packing and distribution. Common causes are contact with other fruit, tree limbs, pickers, bins, grading equipment and any un-cushioned surfaces. The severity of impact damage in the fruit is primarily related to height of fall, initial velocity, number of impacts and type of impact surface. Small fresh, watery or translucent bruises which are not discoloured will normally heal in a short period of time in storage.

Some cultivars are more susceptible to bruising than others. Bruises are more visible on green or yellow apples, as the red colour often masks bruises on red apples. Apples become more susceptible to bruising as they mature; fruit firmness and turgor level will also alter susceptibility. Fruit harvested wet will show an increase in finger bruises. Fruit picked into padded buckets will have less bruising than fruit picked into bags; gentle filling of bins by the pickers reduces bruising. More bruising occurs when bins are carried on the back of the tractor rather than the front, and the state of the internal orchard roads will influence bruising. Transport of bins from the orchard to the packing shed can be a major source of bruising, with air suspension in trucks being preferable to spring suspension. Bruising increases the susceptibility of fruit to blue mould decay, a fungal disease found in most packing sheds.

See **Avoiding bruising in the packing shed (Section 4)** for further information on bruising.

Limb Rub

Limb rub marks are produced by fruit rubbing against limbs, or sometimes leaves, as the fruit matures. They are generally recognized by a scar which is smooth to hard, sometimes bark-like and the colour varies from light brown to black. There is normally a corky or hard mass of tissue beneath the skin marks.

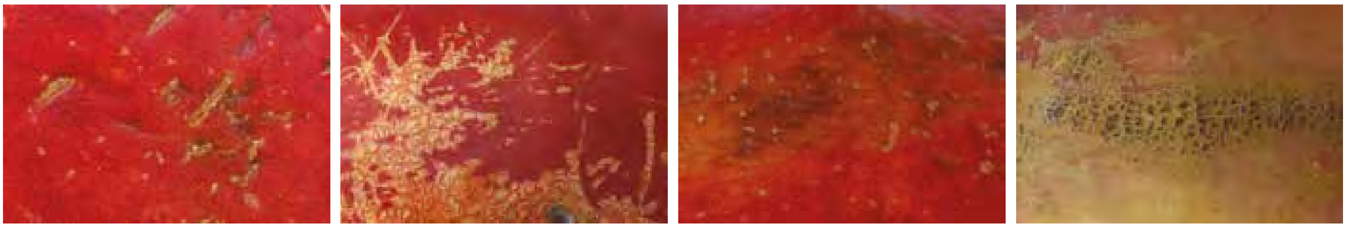


Figure 12. *Examples of limb rub.*

Hail damage

Hail damage can occur at any time during the season. Damage will vary depending on the growth stage of the fruit, size/shape of hailstones and the duration of the event. Injury can range from torn/shredded leaves and small dents in the fruit to loss of the entire crop due to physical damage and bruising. Bark injury can also result, particularly on young trees and younger wood, and stems and branches can be broken. Damage to the bark and/ or fruit cuticle provides an entry point for fungal diseases, so fungicide application may be necessary.

Abrasions, cuts and punctures

External damage on the fruit skin can be caused by friction and abrasion against bin walls and handling equipment. Cuts and punctures are caused by inappropriate handling or equipment and can be avoided by proper care.

5. Flesh firmness

Firmness is important to the 'crunch' and bite quality of apples. Firmness is related to both the size and number of cells within the fruit. Firmer fruit can be achieved by increasing cell numbers while keeping cell size to a minimum; large cell size generally means softer fruit. Firmness is affected by tree vigour, crop load, calcium, nitrogen and phosphorous levels in the fruit, irrigation management, use of growth regulators and seasonal variation in weather.

Firmness can be used as one of the indicators of maturity as a gradual decrease in flesh firmness occurs as the apple reaches full size and starts to mature, but because it is affected by seasonal and orchard variability it is not reliable. Apples less than 5.5kg firmness at the point of sale are considered to be lacking in firmness and not acceptable.

Fruit flesh firmness is measured as the resistance of the apple flesh to penetration using a penetrometer (with an 11mm plunger). Hand-held penetrometers are widely used, but can give very variable results depending on the operator and whether they have been calibrated. As the skin distorts the result of the firmness test, it must be removed from the test area, however the depth of the cut will influence the reading - the deeper the cut the higher the reading. The sun-exposed side of the fruit is generally firmer than the shaded side, so consistency is required in position of the measurement.

The procedure for measuring flesh firmness is described below in the section **Determining harvest maturity**.

6. Starch and sugar content

As the apple ripens, starch changes to sugar. Starch hydrolysis begins in the core area and progresses outwards with starch levels declining rapidly from the start of the respiratory phase. Starch is one of the standard measures of fruit maturity but is not regarded as a quality component in its own right. The hydrolysis of starch corresponds reasonably well with increasing ethylene status during the harvest period.

Sugars are the major soluble solids in fruit juice and therefore the level of total soluble solids (TSS) is often used as an estimate of sugar content. Refractometers are used to measure the percentage of soluble solids in juice, the unit given is degrees (°)Brix. Typical sugar content of apples at maturity is around 12°Brix. Retailers typically set minimum sugar levels for each cultivar.

Sugar levels are influenced by the leaf to fruit ratio, hence anything that increases leaf size and optimises photosynthesis throughout the canopy will aid in accumulation of sugar in the fruit. Sugar content can be influenced by a range of factors such as irrigation, nutrition, weather and position on the tree.

7. Organic acids

The higher the level of organic acids, the more tart the flavour of the fruit. The pH of fruit tissue is governed by the potassium/organic acid balance. In ripe fruits the pH is normally lower than 4.2. The main organic acids in apples are malic, citric and lactic acid.

Acidity is measured by titration. This, combined with TSS provides a sugar/acid ratio. The TSS/Acid ratio is low at the beginning of the ripening process and increases as fruit acids are degraded during ripening. Low acidity at harvest results in poor organoleptic quality following storage, and fruit will have low consumer acceptance.

A minimum level of acidity and flesh firmness are required at harvest, below which apple fruits are not recommended for storage.

Pre-harvest factors influencing fruit quality

Genetics (cultivar/strain and rootstock) play a role in fruit quality, as do orchard factors such as site, planting density, tree training system, tree age, virus load and soil type; and environmental factors (light, temperature, rainfall, humidity), but once the orchard is established the grower has no control over these.

Cultural practices imposed by the grower have a major impact on fruit quality; hence to maximise quality it is essential to use appropriate cultural practices that encourage healthy tree development, including:

- canopy and crop load management
- balanced nutrition program
- irrigation management
- pest and disease management
- appropriate spray application and timing
- orchard floor management
- orchard hygiene

While fruit quality is influenced by both pre- and post-harvest factors, quality cannot be improved after harvest. The quality on the tree is the starting point for post-harvest life, so the quality of fruit coming out of storage is dependent on the quality going into storage.

1. Crop load management

Crop load is the major factor influencing regularity of cropping and fruit size. An understanding of the mechanisms involved in flowering and fruit set can assist in managing crop loads, resulting in improved yields, fruit quality and returns.

(a) **(b)**

Figure 13. *'Delicious' trees showing (a) ideal crop load with large well-spaced fruit, and (b) excess crop load.*

Flower initiation and bud quality

Apple trees flower and bear fruit on spurs, short shoots and one-year-old wood. Flower initiation occurs in the spring and summer of the season before flowering. Buds on spurs and short terminal shoots begin initiation 3–6 weeks after bloom, while axillary buds on extension (first year) wood are formed later in the season, usually as shoot growth slows in mid–late summer.

Once flower buds have been initiated, the quality of the developing buds will be reduced by anything that lowers the amount of assimilates produced through photosynthesis, or that diverts these assimilates away from the buds. Late-initiated flowers often develop only partially and are usually of poor quality. Factors that can lead to reduced assimilates available to the developing buds, thus reducing their quality, include:

- excessive vegetative growth
- lack of light or shaded buds
- poor leaf quality through inadequate nutrition, irrigation or disease/insect attack
- heavy crop load
- high temperatures during the bud development phase causing trees to shut down.

Fruit set

Flowers differ in their potential to set and retain fruits – known as flower quality, and there is a correlation between flower size and eventual fruit size. Flower quality is commonly estimated by measuring the effective pollination period (EPP). High quality flowers have an EPP of 4–5 days, while an EPP of one day is classed as poor quality – these flowers set fruit only when pollinated on the day of opening.

The time window for effective pollination and fruit set is much smaller for poor quality flowers compared with high quality flowers, so the aim is to encourage high quality flower production on spurs and short terminal shoots.

Biennial bearing

Biennial bearing is the production of a heavy crop one year followed by a light crop the next year (Figure 14). It is due to lack of floral initiation in the on-year, leading to poor return bloom the following year. The seeds in the developing fruit produce auxins that inhibit flower initiation, thus the heavier the crop load during the initiation period, the fewer flowers initiated.

Figure 14. *The Biennial Bearing cycle*

Biennial bearing can also be induced by climatic conditions, stress or orchard management practices. Some apple cultivars are less prone to biennial bearing than others – these regular bearers have a high incidence of natural spur extinction (Figure 15).

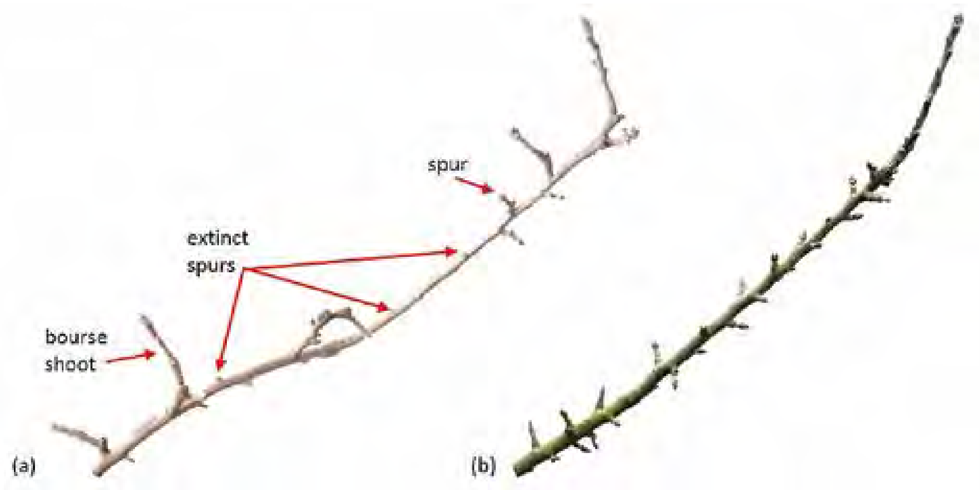


Figure 15. *Fruiting branches showing spur distribution in regular and biennial bearing cultivars: (a) 'Granny Smith' – a regular bearer showing a low spur density with numerous extinct spurs and a high frequency of bourse shoots; (b) biennial bearing spur type 'Delicious' with a high spur density - (Photos courtesy of Tustin et al, PFR, NZ).*

Why is early crop load management so important?

Apple trees experience a natural December drop, but this is insufficient to achieve optimum crop loads, fruit size and quality, or to prevent biennial bearing. As discussed above, flower initiation for the following year begins shortly after fruit set, and trees that carry heavy crop loads over this period will have reduced flower buds the following spring. Hence, to ensure regular bearing and optimal fruit quality we need to manage crop loads early in the season, and in an on-year this means removing over 90% of the potential fruitlets within six weeks of bloom. It should be noted that trees that are not carrying excessive crop loads tend to have a very small, or no, natural fruit drop.

The first six weeks after flowering is also when cell division occurs in the developing fruitlets, and maximising resources during this period of fruit growth will maximise both fruit size and internal quality. Leaving excess fruit on the tree during this period is a waste of the tree resources, as growth is put into fruit that is later removed. It is more productive to channel this energy into fruit that will remain on the tree through to harvest. This is particularly important in drought years when water resources are scarce.

The negative relationship between crop load and fruit size is well known (Figure 16a), but high crop loads can also have a negative effect on fruit firmness (Figure 16b) and sugar content (Figure 16c). Hence, strategies such as the use of substantial removal of flower buds during dormant pruning, and application of blossom thinners early in the flowering period, provide an excellent chance of maximising fruit quality, and thus returns to the grower.

The earlier that excess flowers/fruit are removed, regardless of the method, the larger the size and better the quality of fruit at harvest.

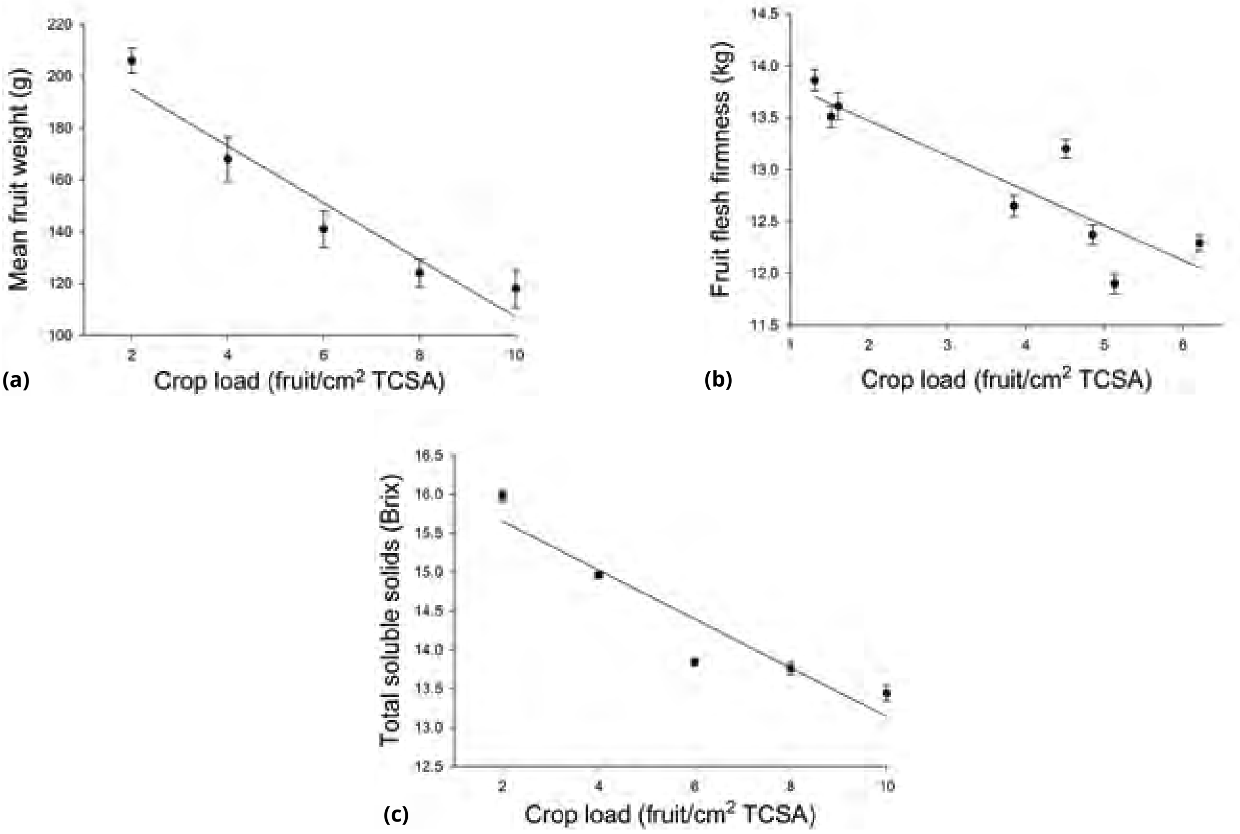


Figure 16. *Impacts of crop load on (a) fruit size, (b) fruit firmness, and (c) fruit sugar content.*

Tools available for managing crop load

Crop load has been managed over the last few decades by pruning and chemical thinning, followed up with hand-thinning. A new tool introduced into Australia recently is artificial spur extinction (ASE). This method of crop load management stems from observations that regular bearing cultivars have high natural spur extinction, and enables crop load to be precisely managed to consistently achieve target yields.

(i) Chemical thinning

There are many interacting factors influencing the thinning response of chemical thinning agents, including cultivar, climate, pollination and tree history. While our knowledge of chemical thinning and tree response has come a long way, juggling application of chemicals with unstable spring weather conditions is a fine balancing act, and responses from chemical thinning can be unpredictable, making optimal crop load management a difficult task.

A structured program combining both blossom and post-bloom chemical thinners will give the most reliable results. There is a range of chemical thinning agents available in Australia (Table 1), but to achieve good thinning and fruit quality, all chemical thinners need to be applied at the appropriate physiological stage and under the climatic conditions best suited to each chemical. Choice of thinning chemical is important, as some cultivars do not respond well to some chemicals.

Table 1: *Chemicals available for thinning of apples in Australia*

Generic name	Chemical name	Trade name/s	Type of thinner
ATS	ammonium thiosulfate	Thin-It®, Culminate®, Biothin®	Blossom
benzyladenine (BA)	N-(phenyl)-1H-purine 6-amine	MaxCel™, Exilis®, BAPSol™, Abscission, Eurochem 6-BA	Post-bloom
Carbaryl	1-naphthyl (N)-methyl carbamate	Bugmaster®, Carbaryl 500SC, Carbaryl 800WP	Post-bloom
ethephon*	2-chloroethyl phosphonic acid	Ethrel®, Ethin™, Promote®,	Blossom
lime sulfur	polysulfide sulfur		Blossom
NAA	1-naphthalene acetic acid	NAA, NAA 20, NAA Stop Drop	Blossom

**ethephon is not registered for thinning in NSW*

(ii) Artificial Spur Extinction (ASE)

Also referred to as bud extinction, ASE is a crop-load management method using bud selection and thinning techniques to precisely define where and how much fruit is set on the tree. This precision method of crop-load control is done before bud break, effectively partially thinning the tree before flowering and also markedly reducing the tree total floral bud load (typically by 50% or more) compared with that of unmodified trees.

Because bud numbers are set in late winter, before growth starts in early spring, trees begin spring growth in an already significantly 'crop thinned' state, so at bud burst, ASE trees will be carrying fewer, but stronger, flower buds than conventional trees. Hence trees can direct more resources into these buds, potentially carrying a more optimum crop load of quality fruit for the tree size and structure. ASE eliminates the need for chemical thinning.

Chemical thinning vs ASE

As noted earlier, the earlier that excess flowers/fruit can be removed, the larger the size and better the quality of fruit at harvest.

If opting for chemical thinners, it is important to implement a structured program using both bloom and post-bloom thinners. However, chemical thinners are not capable of spacing fruit evenly and it can be difficult to apply chemicals at the correct times and under optimal conditions due to the unpredictable spring weather conditions in Australia.

ASE offers a new technology to precisely manage the crop load, maximising cropping on the strongest buds in the tree and spatially distributing buds so that fruit develops optimally. There is also the advantage that it is not weather dependent.

To maximise the benefits of any crop-load management technique or program, good overall tree management is important – the greatest benefits are achieved where all aspects of fruit production are well managed, for example where an orchard is subjected to water stress or nutrition is lacking, regulating crop load is unlikely to substantially increase fruit size or quality.

2. Pruning and light management

Vegetative wood in a tree competes with fruit for resources and, as developing fruit are weak sinks compared with vegetative growth, fruit size is reduced by competition with vegetative shoots. Pruning practices influence both light distribution and age of bearing wood. Dormant pruning stimulates growth near the pruning cut, resulting in increased vigour and shading within the tree. As well as reducing fruit set and hence yield due to poor flower quality, shading also reduces red fruit colour, soluble solids content and fruit size. Tree row orientation has an impact on fruit quality, with lower yields and poorer fruit quality on the south side of trees, while the more exposed northern side tends to be more prone to sunburn.

Summer pruning is often undertaken to improve fruit colour, but this practice can reduce fruit size and soluble solids content, particularly if leaves in close proximity to the fruit are removed, as these are a major contributor of assimilates to the developing fruit.

Fruit from lightly pruned trees tend to exhibit more russet than fruit from hard pruned trees, possibly because lightly pruned trees have denser foliage, thus reduced air movement and slower drying of fruit after damp/wet conditions.

Figure 17. *Different levels of pruning in 'Fuji', from light (left) to hard pruned (right)*

In netted orchards light management is particularly important to maintain yields and fruit quality. Cropping should be reduced to maintain balance with the reduced resources.

3. Nutrition

Orchard nutrition has a direct influence on fruit quality, both at harvest and during storage. The nutrients that are linked most often to fruit quality attributes and disorders include nitrogen (N), potassium (K), phosphorous (P), calcium (Ca) and boron (B). Fruit mineral status can be a useful tool to predict fruit quality – understanding the relationship between pre-harvest mineral content and post-harvest quality can be invaluable in developing storage strategies for the crop. While leaf mineral analysis is commonly used as a tool to determine the nutrient status of trees, the relationship between leaf and fruit nutrient content is poor.

Both lack of nutrients and excessive nutrient availability can impact on fruit quality, either directly or as a result of excessive tree vigour or poor tree health resulting in a lack of vitality making the tree more susceptible to pest and disease attack. The uptake and movement of nutrients within the tree is through either active secretion or passive leakage mechanisms, or a combination of both for some elements. For instance, N is readily moved (highly mobile) within the plant and is remobilised out of leaves back into the storage organs in the trunk when trees go into dormancy. Other highly mobile nutrients are: P in the form of phosphate, K, magnesium (Mg), chloride (Cl) and zinc (Zn). However, Ca is not remobilised (immobile) and will remain locked in the leaf, even when the leaves start senescence and fall. Other immobile nutrients include B, sulphur (S) iron (Fe) and copper (Cu).

Requirement for nutrients is often time related, and varies for different organs on the tree; for example, buds require high N levels in spring to assure good fruit set, but high levels in summer can be detrimental to fruit quality. Boron is also required for early bud break and good fruit set, but is not readily taken up by roots until the soil is warm enough, so the early supply must come from storage or from foliar application. Calcium is important for cell division, elongation, and fruit growth, it is transported via the xylem in the early growth stages until the loss of xylem availability to the fruit.

Nitrogen

Nitrogen is a key catalyst for photosynthesis and a component of amino acids, the building blocks of proteins; it is also a significant component of nucleic acids (DNA). As it is important for cell division and growth of young tissues (e.g. buds, flowers, leaves), it has a major effect on yield and quality.

Fruit quality is reduced by excessive N levels. High N availability during the season results in excessive shoot growth that competes with the developing fruit for resources and increases shading within the tree, thus reducing fruit size and depressing red colour development. It can also decrease lignification of shoots making them more susceptible to winter frost damage, and trees with excessive N can be more susceptible to disease attack, and at risk of premature fruit fall. A negative correlation is often observed between N content and fruit firmness. Fruit high in N at harvest are more subject to pre-harvest drop and more likely to be affected with physiological disorders such as cork spot and bitter pit; they are also more likely to develop storage disorders. A low N:Ca ratio is associated with good storage quality.

Nitrogen deficiency results in small fruit that matures early and is highly coloured.

Phosphorous

Phosphorous is involved in energy transfer within the cell and the maintenance of cell membranes. It has a direct effect on tree health and increases fruiting potential by increasing flower number; it is also important in determining fruit size, firmness, colour and storage potential. Low P increases the susceptibility of fruit to low temperature and senescent breakdown.

Potassium

Potassium is important for eating quality of the fruit. Apple fruit is a strong sink for K, and soils with high levels of K produce fruit with optimum sugar to acid ratio and fruit size. Potassium is highly mobile in the phloem and K levels remain relatively stable from fruit set through to maturity. Potassium is positively correlated with red skin colour, but high rates can decrease firmness. Excessive application of K can adversely affect fruit quality as a result of competing with, and restricting, calcium uptake. This results in fruit with high K:Ca ratios which increases the risk of Ca-related storage disorders, both fungal and physiological.

Trees deficient in K exhibit reduced leaf photosynthesis, and biosynthesis of sugars and organic acids is inhibited, producing small fruits with lower soluble solids content, often with a thickened skin. When K is deficient, uptake of calcium and magnesium is usually increased.

Calcium

Calcium activates enzymes and is essential for cell division, elongation, and fruit growth. It stabilizes and ensures permeability of the cell wall, protecting it from degradation by enzymes. Consequently fruit with high calcium levels are firmer with reduced leakage through cell wall membranes and hence are less liable to breakdown disorders. Calcium plays an important role in the susceptibility of fruit to physiological disorders and fungal diseases. Good calcium supply delays ripening and fruit senescence, thus increasing storability of fruits.

Calcium is transported from the roots to the leaves and developing fruitlets via the xylem. It is relatively immobile in the phloem tissue so it cannot be remobilised from older tissues, hence young leaves are the first to show symptoms of deficiency, new growth becomes stunted and fruit yield may be reduced. Xylem functionality to the fruit is lost around 60 days after bloom, so further growth and mineral supply becomes dependent on the phloem; hence it is vital to ensure early season Ca application along with irrigation to get the Ca content of the fruit up prior to the loss of xylem functionality.

In Ca deficient trees the concentration in fruit becomes diluted as the fruit expands and crop quality deteriorates with reduced firmness and increased incidence of physiological disorders such as cork spot, sunscald and bitter pit.

Pre-harvest foliar Ca sprays can be used to supplement calcium levels. Post-harvest CaCl2 applications can reduce the decay caused by Penicillium and other fungal diseases.

Boron

Boron is the micronutrient needed in greatest amounts both in the fruit and leaf, but there is a relatively narrow margin between deficiency and toxicity. Boron is involved in cell wall formation, stabilisation and lignification, and xylem differentiation, hence is important for ensuring normal development of new tissues. As B is responsible for pollen germination and pollen tube formation and activation, deficiency results in poor flower and fruit formation. Unless the deficiency is severe, symptoms are frequently found in the fruit with little sign of deficiency in the leaves. The most common symptom is small, water-soaked areas in the fruit flesh which may dry out, leaving spongy lesions. Severe deficiencies lead to deep cracks in the skin. If both B and Ca are deficient fruit is of poor storage quality and bitter pit is more common. Boron is not readily translocated within the tree, so foliar applications are used to target key periods of flower and fruit formation in order to maintain flower set and fruit quality.

Boron toxicity results in chlorosis of leaf margins and tips, followed by necrosis. In fruit, high levels lead to a reduction in storage quality – fruit softening.

4. Irrigation

Irrigation has a significant effect on yield, fruit size and fruit colour intensity, so to maximise yield and fruit quality, good irrigation management is important to match the crop's water requirement to the water supply. Adequate soil moisture during the first 1-2 months is critical for retention of fruitlets and for initiation of flower buds for next season's crop. Hence irrigation should commence at green tip and, to avoid water stress, should continue until after harvest. Insufficient water results in drought stress and reduced fruit quality, with poor size and colour; premature fruit ripening or fruit drop can also occur.

Applying more water than the crop requires is just as damaging as lack of water. Nitrogen, sulphur and boron are leached out of the root zone leading to nutrient deficiencies. Water-logged soils are poorly aerated and the lack of oxygen causes severe injury to the root system, resulting in lack of mineral uptake. Water logging during the bloom and fruit-set period reduces fruit set and retention. Premature fruit ripening and decrease in fruit quality are characteristic in trees in water-logged soils. Root systems also become more susceptible to fungal dieback and crown and collar rots.

5. Spray application

Failure to achieve effective coverage when applying chemicals in the orchard results in poor pest/disease control or ineffective uptake of plant bio-regulators (PBRs). This can lead to a reduction in fruit quality through direct damage caused by pests and diseases or uneven application of PBRs. Spray coverage can be checked through a variety of methods, including fluorescent dyes, water sensitive paper, water soluble food dyes or clay based products.

Figure 18. *Checking spray coverage with, from left to right: fluorescent dye, water sensitive paper, and kaolin based spray.*

There are several chemicals and surfactants known to cause phyto-toxicity and skin damage. Sprays containing heavy metals, particularly copper and zinc, have been implicated in russet development. Other chemicals reported to induce russet include urea, dodine, and fungicides based on dimethyldithiocarbamyl compounds. Foliar nutrients and commercial sunscreens applied during the sensitive fruit development period can be problematic.

Sulphur can induce russet. Although it is often credited for russet reduction, this is the result of reduced levels of fungal infection leading to a reduction in russet, and not the sulphur itself improving skin finish. Sulphur phyto-toxicity is increased when the chemical is applied under warm to hot conditions.

Any chemical spray applied under the wrong weather conditions, particularly during the critical fruit development period, is capable of causing skin damage in the form of russet. For example, carbaryl will cause skin russeting if applied under cool temperatures or high humidity, and NAA may cause russet under humid conditions.

Application of any chemical after a prolonged cool wet period is likely to result in an increase in fruit russet as the skin is softer and more susceptible to damage.

Differences in chemical formulation can affect the russeting potential of pesticides. Emulsifiable concentrates are more likely to cause damage than wettable powders. Inert ingredients and added surfactants may also cause problems. Surfactants increase russeting through their effects on wax formation on the fruit cuticle. Normally the wax layer repels water, however surfactants can solubilise the wax, thus changing the configuration of the platelets and reducing the protective nature of this water barrier.

Interactions between chemicals used in a spray program can also have deleterious effects on yield and/or fruit quality. Application of NAA at full bloom following Cytolin at king bloom will result in severe over-thinning, as will use of paclobutrazol on 'Delicious' within 7 days of a carbaryl spray. Applying NAA later than 7 days after full bloom when a Cytolin program has been used produces pygmy fruit. Delan is also known to be incompatible with petroleum oils, alkaline materials, and sulphur containing compounds.

Spray volume can impact on fruit skin finish. Low spray volumes tend to result in cleaner fruit. Slow drying conditions are likely to cause skin russeting, particularly when high water volumes have been used.

6. Orchard hygiene

Good orchard hygiene can reduce disease and insect pressure by removing inoculum sources or overwintering insects. Spores may overwinter on diseased and mummified fruit left on trees or on dead wood. Fruit should not be left hanging on trees after harvest – diseased or damaged fruit can be removed from the orchard or dealt with by throwing into the inter-row where it can be mulched by mowing. Prunings and dead branches should be removed or mulched in the orchard and prunings infested with scale should be burned. Picking bags, harvesting and storage bins and equipment used in the orchard should be cleaned and disinfected each season to remove inoculum sources.

Many pathogens causing post-harvest rots (Mucor and Phytophthora) are soil borne, so every attempt should be made to isolate fruit and handling equipment from the soil. This includes pruning of low branches that are likely to result in fruit contacting the ground. At harvest, fruit that has been in contact with the ground and fallen fruit should not be placed in the bin with other fruit. Bins contaminated with soil should be cleaned and disinfected before use.

Some pests such as codling moth can overwinter in crevices in bins, use of plastic bins will prevent this. Wooden bins should be regularly cleaned using steam and/or pressure washers. Bins should be stacked away from trees.

In fruit fly infested areas waste fruit should be removed from the orchard and soaked for 4-5 days in water topped with a layer of kerosene. It can also be frozen or boiled, pureed and fed to poultry or pigs.

Weeds, particularly broad-leaf species, can be a food source for some insect pests, and provide a habitat for egg laying (eg. Heliothis, loopers. Light Brown Apple Moth). Good weed management, particularly during dormancy and early spring may reduce the number of larvae that can migrate to trees. Rubbish on the orchard floor provides a habitat for weevils, so maintaining a weed-free strip under the trees and a neatly mowed inter-row will reduce weevil numbers.

Mite and mealy bug infestations tend to be worse on dusty trees, so limit orchard traffic in hot, dry conditions and drive on the downwind side of blocks if possible. Always drive slowly in the orchard and wet down tracks where feasible to minimise dust clouds.

Practicing good sanitation and hygiene will help prevent the entry and movement of pests onto or around your property. Workers, visitors, vehicles and equipment can spread pests, so make sure they are decontaminated before entering and leaving the property. Have a designated visitor's area and provide vehicle and personnel disinfecting facilities.

Fruit maturity

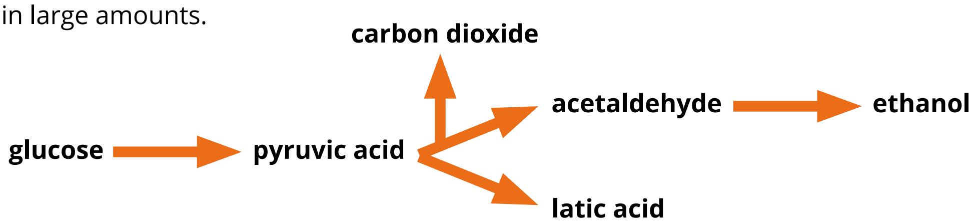
The timing of harvest is critical to the quality and post-harvest life of apples. As a climacteric fruit, apples can be harvested once they reach physiological maturity and before they are horticulturally mature or 'ripe' and ready for consumption (appearance and marketability). Apples will continue to ripen after harvest if physiologically mature. The process of ripening involves both physiological and biochemical changes within the fruit, including:

- softening of the flesh as a result of the breakdown of bonds between adjacent cells – protopectins in the cell walls form soluble pectins which in turn degrade into sugars
- change in background colour from green to yellow, resulting from the degeneration of chlorophyll in the skin
- conversion of starch to sugars (starch hydrolysis)
- loss of acidity
- synthesis of aromatic compounds
- synthesis of oils and waxes that contribute to skin greasiness.

These changes are accompanied by an increase in respiration and an increasing sensitivity to ethylene. Respiration is the process whereby stored carbohydrates are broken down (oxidised) to form carbon dioxide (CO_2) and water with the release of energy, which is used to maintain the living cells.

glucose + oxygen —enzymes→ **carbon dioxide + water +energy**

If atmospheric oxygen is limited, oxidation will be incomplete, producing either lactic acid or acetaldehyde and ethanol. In small amounts these contribute to the fruit aroma, but cause cellular damage and undesirable taints in large amounts.



Respiration is measured by determining the rate of CO_2 production. The respiration rate in apples is high during early fruit development and rapidly drops to a minimal rate prior to harvest (preclimacteric minimum).

Fruit picked before reaching physiological maturity are more prone to shrivelling through moisture loss, superficial scald and bitter pit, and will never reach optimal eating quality. Over-ripe fruit is likely to become soft and mealy with poor flavour and is prone to yellowing, internal browning and water-core.

The terms maturity and ripening describe different processes - maturation ceases at harvest but ripening and senescence continue.

Eating quality is closely related to the ripening stage of the fruit. Maximum eating quality occurs at the peak of the climacteric rise or just before; but for long storage life fruit needs to be picked earlier, at the beginning of the ripening phase. Picking at the correct stage of maturity for the intended market is probably the single most critical factor affecting quality to the consumer.

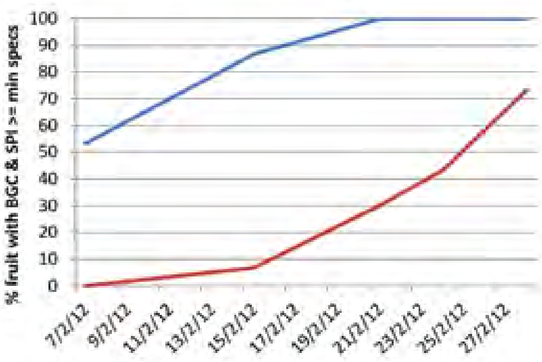
Maturity testing is important because harvesting at optimum maturity minimises disorders and maximises storage life and post-storage quality.

Determining harvest maturity

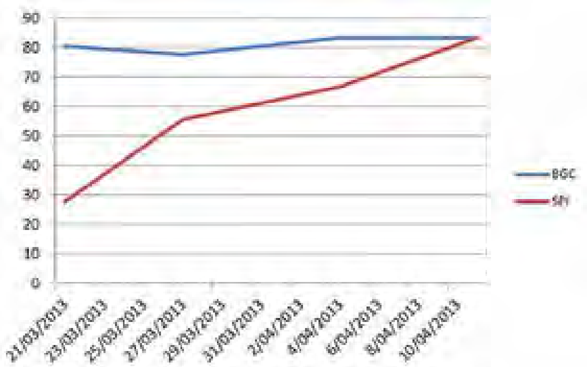
There are multiple indices that can be used to determine harvest maturity, including starch content, firmness, sugar and acid content, skin background colour, incidence of water-core, seed colour, waxiness, respiration and internal ethylene concentration. Some of these are indicators of quality, rather than maturity, but can be useful when used in conjunction with other indices.

Harvest maturity assessments should be based on a minimum of three indices, as each has limitations. Internal ethylene concentration is a major physiological marker and hence is an important determinant of harvest timing, however laboratory facilities are required for its measurement. Commonly used indices include starch pattern index (SPI), flesh firmness, soluble solids content, background colour, and to a lesser extent, titratable acidity.

To determine the optimum harvest date, assessments should be made at regular intervals leading up to harvest. A representative sample of 20 fruit should be collected from each block, and results plotted to show the change in maturity. Graphing the changes in the maturity indices allows an accurate determination of picking time (Figure 19).



(a)



(b)

Figure 19. *Examples of changes in fruit background colour (BGC) and starch pattern index (SPI) prior to harvest.*
(a) 'Royal Gala',
(b) 'Pink Lady'.
Maturity specifications for harvest were
Gala: BGC 4 - 7 (Royal Gala colour swatch); SPI 1.5 - 4 (ENZA 6 point scale)
Pink Lady: BGC F3 - F5 (Ctifl 'Pink Lady' swatch); SPI 2 - 7 (Ctifl 10 point chart)

Firmness

The flesh firmness of apples is measured using a penetrometer with an 11mm plunger. Measurements should be made on fruit that has a temperature of at least 10°C as cold fruit will give a higher reading. Improper use of the penetrometer will result in erroneous readings. Firmness is affected by many pre-harvest factors that are independent of maturity, so it is more a measure of quality than maturity.

Firmness is correlated with storage performance, and most packing sheds will not take fruit for long-term storage if firmness is below 6.5kg. Fruit can soften 0.5-0.8kg during storage and a further 0.7-1.0kg following removal from storage. Wholesalers commonly use firmness as a quality indicator.

Figure 20. *Hand-held penetrometer for measuring fruit firmness.*

Procedure

1. Remove a small piece of skin (size of a 5 cent coin) using a vegetable peeler or small knife. Note that the depth of the cut will alter the firmness reading – the deeper the cut the higher the firmness value, so ensure consistency on all fruit samples
2. Hold the apple firmly and place against a solid object such as the bench
3. Place the penetrometer tip on the cut area and push slowly into the fruit with even pressure until it has penetrated to the mark on the plunger shaft (1cm)
4. Pull out the plunger and record the reading to the nearest 0.25kg
5. Average the score from the whole sample (20 fruit)
6. Graph the result.

To improve consistency and reduce variability in firmness readings, hand held penetrometers are mounted in a drill press to ensure the same speed of force is applied to each fruit tested. The greatest cause of false reading comes from applying pressure too fast. The correct speed is approximately two seconds. This can be achieved by saying to yourself, "1,001, 1,002" as you insert the penetrometer's plunger into the fruit.

It should be noted the readings obtained may not truly represent the condition of the apple being tested for a variety of reasons: N levels from different areas in the fruit can vary widely; the greater the water core area in a fruit, the higher the firmness readings.

Soluble solids concentration (SSC)

Sugar levels increase rapidly during the ripening phase, but like firmness, SSC is affected by many pre-harvest factors and is only partially influenced by fruit maturity. Most markets require a minimum SSC of 10%.

A refractometer that measures the optical density of a solution is used to determine SSC. Either a hand-held or digital refractometer can be used (Figure 21). Sugar levels vary throughout the apple, so it is important to standardise where the juice is extracted from (e.g. the equator of the non-blush side).

Procedure

1. Calibrate the refractometer using distilled water
2. Squeeze sufficient juice onto the refractometer prism (hand-held) or into the well (digital) to cover the surface
3. Read the level and record the result
4. Average the score from the whole sample (20 fruit)
5. Graph the result.

Figure 21. *Hand-held and digital refractometers for measuring fruit soluble solids content*

Starch index

The starch index is the most reliable single maturity test for most apple cultivars. The test uses an iodine solution to indicate the amount of starch in the apple – the distribution of starch in the fruit tissue is characterised by staining that appears when iodine reacts with starch present on the surface of freshly cut fruit. The reaction leaves starch saturated areas with a blue/black stain. Starch hydrolysis starts in the core and extends out into the flesh as the apple ripens, either in a radial or concentric pattern. Each cultivar has a typical pattern of starch disappearance, and many starch charts are available, either generic (Figure 22) or specific to cultivar (Figure 23).

Iodine solution

A standard solution is made by dissolving 10g potassium iodine and 1.5g iodine crystals in 1 L water. The solution breaks down rapidly in light, so store in a sealed glass container wrapped in foil.

Procedure

1. Cut apple in half across the core (equator) using a sharp knife (see Figures 22 and 23 below)
2. Pour iodine into a flat container to a depth of 5mm; a sample of 20 fruit will require approximately 50ml solution
3. Dip the cut surface of the calyx half of the fruit into the solution for at least 30 seconds
4. Remove from solution, blot excess and lay face up for at least 45 seconds
5. Compare the stained flesh pattern with a starch conversion chart
6. Average the score from the whole sample (20 fruit)
7. Graph the result.

Figure 22. *Generic starch pattern index chart.*

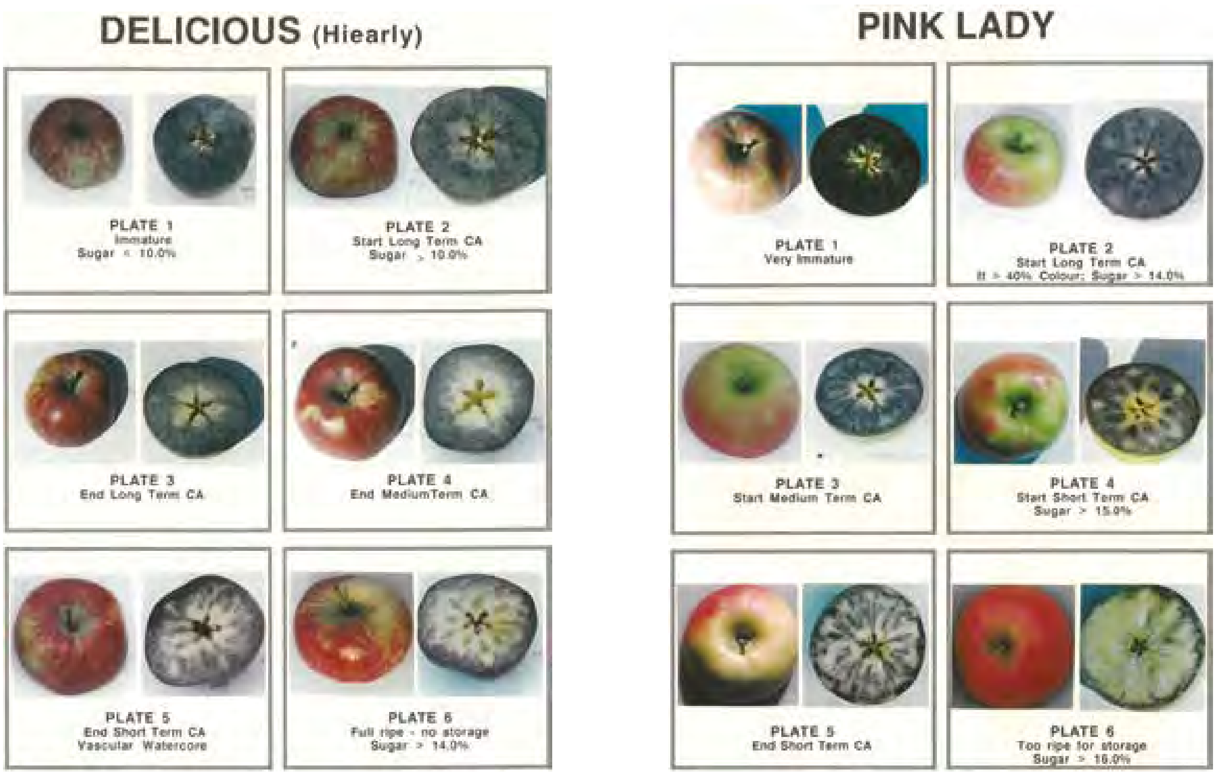


Figure 23. *Examples of cultivar specific starch pattern index charts (from Little 1999)*

Background colour

As fruit mature and ripen the loss of chlorophyll from the skin is reflected by the change in background skin colour from green to yellow. Colour is assessed on the non-blush part of the fruit by comparison with colour charts or using a chromameter (colour meter).

Figure 24. *Assessing skin background colour (top) ENZA Gala background colour swatch, (bottom) Pink Lady background colour categories published by Agriculture WA & Australian Apple & Pear Growers Association.*

Maintaining quality postharvest

Many post-harvest physiological disorders are the result of pre-harvest management. Hence an understanding of the impacts of orchard management is critical to managing fruit quality and close links need to be maintained between the grower and the packing shed.

Apples are alive and continue metabolic processes after harvest. Without appropriate handling at all stages along the supply chain, from producer to consumer, fruit will continue to ripen and deteriorate. The main causes of post-harvest losses and poor quality fruit are bruising and other mechanical injury, water loss, under- or over-maturity at harvest, and chilling injury.

Figure 25. *Apple showing latent damage (bruising) after removal from cold storage. Damage occurred either during harvesting or handling before being placed into cold storage.*

Figure 26. *Apple showing the extent of internal latent damage after removal from cold storage. Damage is due to rigorous handing methods before being placed into cold storage.*

Postharvest handling in the field

This section discusses methods to maintain produce integrity through field cooling and handling processes to maximise postharvest quality and storage life.

Cooling your apples is possibly the single most important step in your postharvest handling processes. There are several ways to reduce cooling costs and increase the efficiency of your cooling methods through in-field practices.

It is crucial to keep freshly harvested fruit away from direct sunlight. Fruit that heats up due to sunlight exposure will increase respiration and ethylene production rates and is likely to have a reduced shelf life. Collect filled bins from the orchard as soon as possible, and ensure bins are shaded in the vehicle for transport back to the packing shed.

At time of harvest, fruit temperature is several degrees warmer that the ambient air temperature. To mitigate the effects of temperature it is best to harvest early morning after dew has dried. Cooling your fruit begins in the field and removal of field heat is the single most important step you can take to extend shelf life and maintain product quality.

Pickers should remove any jewellery and trim finger nails prior to harvesting fruit. Fruit should not be dropped into containers. Bins of fruit should not be handled aggressively, or filled to overflowing.

Because apples are prone to damage during field transport to the packing shed, ensure your on-farm roads are smooth to avoid any unnecessary bumps or vibration of the filled bins as they are being transported to the packing shed. Vehicles used to transport fruit should have adequate suspension systems and tire pressure to provide extra cushioning when fruit is being transported to the packing shed. Ideally soft-tire transport should be used in the orchard for transporting fruit.

Despite best efforts some fruit will be inadvertently damaged during or just after harvest. If damaged fruit is sound (no pests or diseases) it can be salvaged and used for processing into value added products, such as jams, ice-cream, jells, lollies, powders, tea etc.

Damaged fruit can be composted and used as an organic conditioner for the orchard soil. To eliminate the risk of pest and diseases infecting your orchard and mitigate any possible food safety risks, waste fruit must be composted correctly.

Avoiding fruit damage

Any damage to the fruit triggers a series of responses to stress. Fruit physiological reactions result in:

- increased respiration and degradation of tissue
- production of ethylene (wound ethylene) that accelerates ripening and rapid softening
- tissue damage leading to production of enzymes and substrates that can affect texture, taste, appearance, aroma or the nutrient value or health benefits
- tissue damage at the site of impact - the resulting cell death reduces overall fruit firmness.

Basically there are three main causes of fruit damage/bruises:

1. *Impact Injury:* caused by the dropping of fruit onto other fruit or onto a hard surface during harvesting or packing
2. *Compression injury:* happens when cellular damage occurs due to the fruit being under pressure from heavier objects. It often occurs during storage and bulk transport. The bottom layer of fruit in a carton on a pallet can experience compression damage and fruit can be deformed. If containers, cartons or the packaging material cannot withstand the weight being exerted upon it from above, fruit often suffer compression damage. Cartons/containers that are over packed often result in the top layer of fruit suffering compression damage.
3. *Abrasion injury:* superficial damage to the skin or calyx of the fruit. Caused by any type of friction (rubbing) of the skin or calyx. This friction may come from other fruit, packaging materials, brushes, rollers or belts.

Note: remember that ethylene removal or neutralisation under controlled or modified atmosphere conditions reduces the speed of healing. Furthermore, atmospheric composition also reduces the rate of stress response.

Harvesting your fruit

Watch orchard apple maturity closely and coordinate picking times. Harvest fruit at peak condition and maturity.

- To maximise long term storage life, apples destined for controlled atmosphere (CA) storage are harvested at a slightly less mature stage compared to apples for immediate sale. Slightly immature fruit bruise easily and have a high disposition to scald (chill injury) and excessive water loss (shrivelling) during storage.
- Apples destined for immediate sale (not CA stored) are harvested at the optimum maturity stage to maximise quality and consumer acceptance (size, colour, starch and brix levels and flavour).
- Train pickers and handlers to minimise damage. Each picker should be trained to inspect and remove undesirable fruit in the field. Set acceptable standards for harvesting and incoming fruit to the packing shed.
- Remove damaged and rotting fruit from the orchard by having strategically placed waste bins in the orchard for pickers to dispose of unwanted fruit. Ensure these bins can be easily collected and removed. This strategy will eliminate disease and pest buildup in the orchard and aid in preventing infection of next year's crop.
- Rain prior to picking results in turgid fruit. Fruit harvested in a fully turgid state will bruise easily when picked and handled. Fully turgid fruit that are bumped or knocked together will show signs of latent damage, especially at time of eating. Picking wet fruit and placing in picking bins will result in heat building up in the centre of the bin, even in well ventilated bins.
- Tractors or picking machines should be able to access the rows without causing damage to trees or fruit, and pallet forks should have easy access and removal from under the bulk bins. Fruit carried over dusty roads can result in contamination and abrasion issues.
- If the orchard floor is in good condition it will facilitate ease of picking. Grade and smooth the roads and orchard rows well in advance to eliminate holes, ruts and machinery tracks. Ruts and tracks may trap water or cause fruit to be bounced or shaken up. Cut the grass short; long grass is a tripping hazard especially when carrying a full picking bag. Attention to these details will facilitate the gentle handling, carrying of fruit and filling of picking bins without causing damage to fruit.

- In-field quality monitoring systems are now becoming available. For example, picking bins can automatically weigh and transmit the volume of fruit picked from pickers to the shed through Radio Frequency Identification (RFID) readers (Figure 27). RFID wrist band are available for individual pickers (Figure 28), enabling monitoring of fruit quality and volumes picked in each bin in real-time. This system enables the monitoring of fruit quality for orchard blocks.

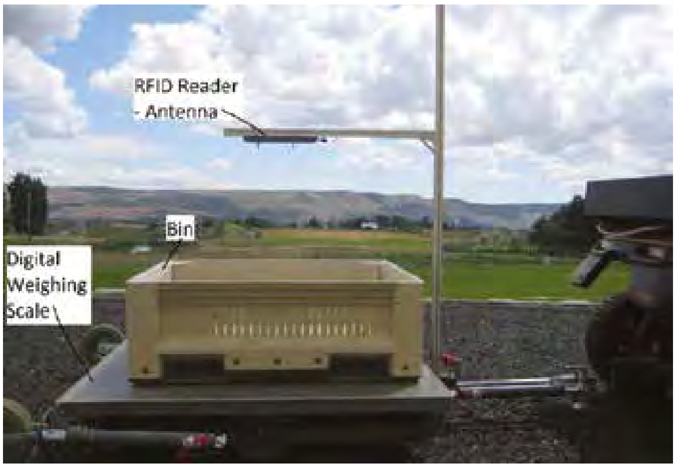


Figure 27. *Picking bin, weighing scales and radio frequency identification (RFID) reader attached to a tractor draw bar. (Image provided by Ass Prof M. D. Whiting Washington University USA).*

Figure 28. *Radio frequency identification (RFID) wrist bands.*

- The apple ripening process can be accelerated by gases (ethylene) and heat from the exhaust of the equipment used to transport and move bins.
- On farm transport routes for the movement of apples should be planned before harvesting commences. (When planning the orchard and planting out trees, harvesting routes should be designated to improve harvesting efficiency by reducing the time that harvested apples spend in the field under the hot sun).
- Time between picking (harvest) and storing of apples is critical to reduce the impact of temperature on your fruit.
- Transfer produce continuously from the field to the packing shed for pre-conditioning and cooling.
- Harvest when field heat is low. This management technique is very effective and reduces internal temperature of the produce by several degrees, resulting in substantial saving in energy costs used to cool the produce.

- Night temperatures are usually >5°C cooler than daytime temperatures. Sometimes it is advantageous to harvest at night under lights.
- Avoid exposing produce to direct sun; store produce in the shade and cover for transport to the packing shed. Bin covers are available to protect fruit from the sun and dust whilst transporting to the shed (Figure 29).

(a)

(b)

Figure 29. *Bin Covers (a) Image from Vineyard Concepts LLC, (b) Image from NetPro*

Curing and pre-conditioning

Removing field heat as quickly as possible is critical to maintain apple quality during the postharvest and supply chain phases to ensure fruit is delivered to customers in the best possible condition. There are several methods of cooling apples, some more rapid than others (Figure 30).

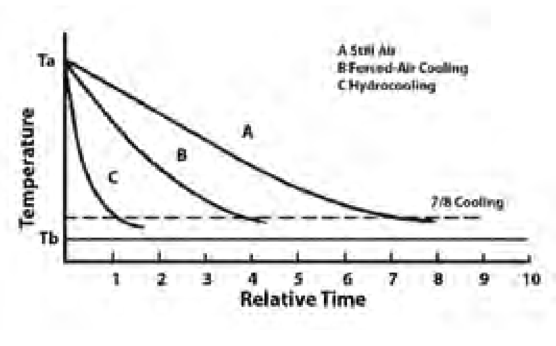


Figure 30. *Temperature changes using three different cooling methods. (Source: North Carolina State Extension Publication, February 1, 1990 AG-413-01.)*

This cooling process for apples is undertaken:

- before placing into storage
- after packing and before setting down in cold storage, or
- before exporting fruit to overseas markets.

Heat treatments

Heat treatment can be applied either as a pre-treatment before fruit are placed into storage or as a market access treatment for exporting fruit. Pre-storage heat treatment can be used to maintain fruit quality, enhance the shelf life of apples and reduce the incidence of fungal diseases.

Pre-storage heat treatment

Research on pre-storage heat treatment has shown that some cultivars have firmer flesh when removed from storage. Heat treatment is reported to inhibit protein synthesis for cell wall degradation by reducing electrolyte leakage and ethylene synthesis after cold storage. This results in apples with better eating quality. However, research has also shown that the response to heat treatment differs between cultivars.

Heat treatment for market access

Heat treatments are used in very specific situations to gain access to markets with restrictions on the use of traditional chemical treatments and in place of radiation. Treatments such as hot air or vapour heat and hot water dips can:

- treat and kill insects (market access and quarantine requirements)
- reduce decay due to disease infestation
- inhibit physiological disorders such as superficial scald

Commercially, heat treatment applications have been difficult due to several reasons:

- challenges with treating bulk loads of fruit
- difficulties in managing the temperature by time margins
- efficacy of fungicide control measures
- stage of maturity
- uneven maturity levels of harvested fruit

Intermittent warming treatments can be used to lessen chilling injury but this is limited to small consignment loads. Large commercial volume loads are very difficult to treat due to the logistics and obtaining uniform patterns within the large loads. The expense of running the refrigeration and heating equipment for bulk cooling loads is also a consideration.

Pre-cooling

Field heat must be removed from apples before placing into storage. Forced air cooling or hydrocooling are used. Information on forced air cooling can be found under **Storage technologies**.

Hydrocooling

Hydrocooling is the fastest method to cool apples and remove field heat. This method uses large volumes of chilled water. Fungicides and scald inhibitors are not easily applied when using hydrocoolers as the volume of clean fresh water and temperatures may cause problems in achieving good coverage and protection in some instances. Hydrocooling is approximately 15 times faster than air. This requires fruit to be cooled by chilled water as close to 0°c as possible, but to save time and energy a temperature around 7°C can be used.

There are several different types of hydrocoolers:

- conventional
- immersion
- truck
- batch

The majority of the field heat can be removed by hydrocooling, follow by methods such as forced air cooling to remove the remainder of the field heat.

The water used to conduct the hydrocooling needs to be high quality to avoid contamination of the apples being cooled. A warm apple surface is an excellent site for postharvest diseases. Once the produce is cooled it should not be allowed to warm up. Hydrocooling water is recirculated and this can be a source of infection. Chlorine in the form of sodium hypochlorite solution is normally used in the hydrocooling water. Water pH and temperature also have an effect on the chlorine solution and its effectiveness. The optimum pH of the water should be around 7. Chlorine can quickly eliminate pathogen organisms, but spores are 10 to 1,000 times more difficult to kill. If the pathogen has already penetrated below the skin surface or entered the core through the calyx end, the chlorine treatment will not be effective. In addition, chlorine treatment can cause surface bleaching.

To increase your understanding of how hydrocooling works a set of simple explanations are provided below.

Heat transfer to the surface of the apple = Heat transfer from the surface of the apple to the chilled water

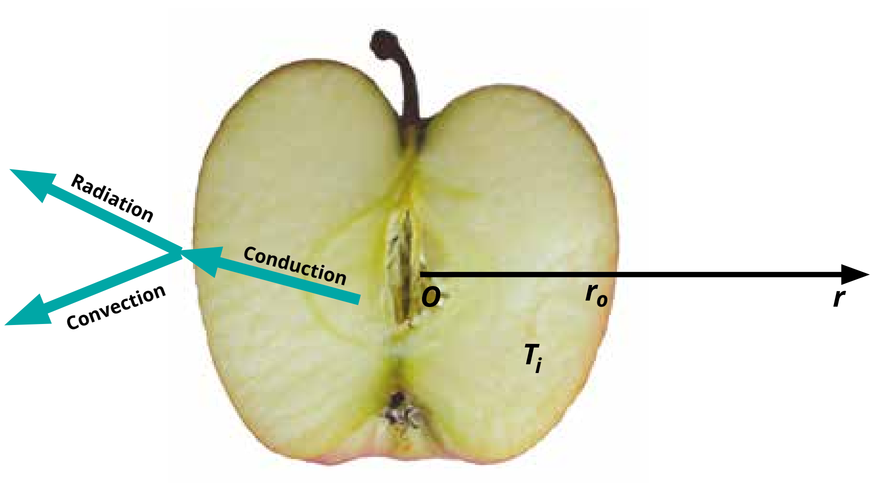


Figure 31. *Heat transfer from an apple*

You must consult the hydrocooler's manufacturer to precisely calculate the time for hydrocooling of your apples to remove field heat.

The following is based on a decimal temperature difference (DTD) for the temperature you wish to achieve using hydrocooling. This has been adapted from North Carolina State Extension Service Publication 1st, October, 1992, Ag-414-04 by Mike Boyette and Ed Estes.

The equation is: DTD = (T-W) / (P-W)

T = target temperature (°C)
W = temperature of the water (°C)
P = starting temperature of the produce (°C)

For example: the centre of a normal sized apple at harvest is 35°C, so how long will it take to reduce to 7°C?

- The target temperature = 7°C
- The hydrocooled water temperature = 2°C
- The starting temperature of the harvested apple = 35°C

Therefore the equation is: DTD = (7 - 2) / (35 - 2) = 0.1

Using Figure 32 below we can now determine the time required for hydrocooling for a DTD of 0.1. Moving down the line for 'Normal size apple' find where the line meets the 0.1 value on the vertical axis - this is approximately 62 minutes.

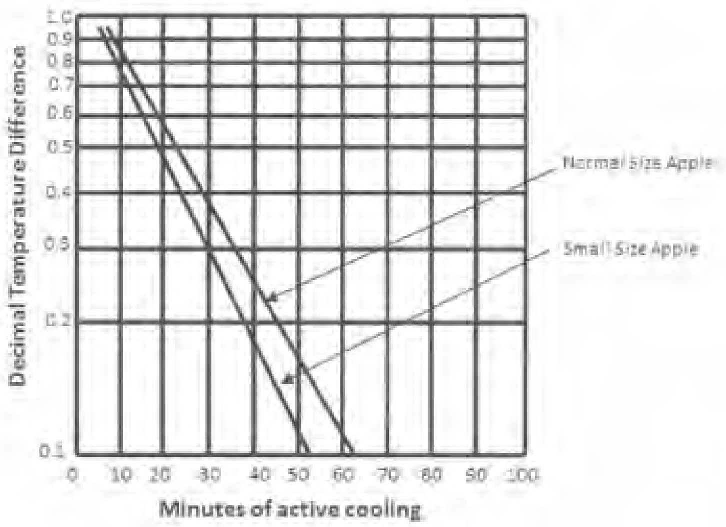


Figure 32. *Determining the time required for hydrocooling*

Tipping/Dumping

Once apples enter the packing shed they are prepared for storage (long or short term) or packaged for sale. Fruit are tipped from the apple bins (often referred to as dumping) at the beginning of the sorting or packing line. Falling fruit can be bruised during this dumping phase. Cushioning to absorb the impact of the energy experienced by fruit being dumped is critical to reduce impact damage. Hence, most packing sheds slowly dump fruit into a water bath (wet dumping) or onto a padded conveyer. Wet tipping or dumping is the most common practice.

Substantial advancements in tippers have been made with roll back lids that allow controlled discharge of fruit from the bin into the water and sanitiser or onto the padded conveyer. Detectors detect fruit flow and adjust the tip angle and rate of tip that allows for a progressive flow of fruit from the bin.

Submerging apples in the hydro handling dump tanks where the water temperature is considerably lower than the fruit temperature can potentially result in apples drawing in water and decay organisms from the dump tank water solution. This is due to the temperature difference between the fruit and immersion water temperature causing the internal air space to contract allowing water and unwanted organisms to enter the fruit.

Apples have a high intercellular space compared to other fruit - 25-30% internal air space of the total fruit volume compared to potatoes (1-2%) and tomatoes (15-20%). Research conducted on mature apples found non-functional stomata and approximately 1.8 lenticels per cm^2 on the skin surface. Apples also have a natural bloom (platelets of wax) on the skin (cuticle layer), loss of natural bloom and nonvisible breaks in the skin, small cuts, punctures or bruises lessens the integrity of the apple to resist infiltration. Cracks in the cuticle are 12 times more permeable than the intact cuticle.

For sound mature apples, infiltration of organisms occurs at the blossom end. Organisms can move up the floral tube into the core of the apple. This can lead to latent core or fruit rots when removed from storage, or breakdown during marketing. Little or no uptake occurs when the immersion water temperature is warmer than the apples being treated.

In addition, Immersion depth and time held in the dump water and sanitation tank has a substantial effect on hydrostatic pressure and infiltration of water and organisms into the fruit.

Lenticel damage after harvest and storage is common in some apple cultivars, particularly 'Delicious'. Lenticel damage occurs in the field prior to harvest or in the very early stages of postharvest storage. Lenticel breakdown (dark spots on the apple skin) is only expressed after a certain period of storage. Research studies have found that lenticel breakdown and bleaching around lenticel openings is less prevalent where potassium chloride was used instead of calcium chloride for bitter pit control in the postharvest immersion dip before storage.

Immersion of some apple cultivars, for example 'Golden Delicious' in 1.5% w/v of calcium chloride as postharvest treatment to control bitter pit, does not prevent scald. However, the immersion treatment of calcium chloride, followed by the application of 1-MCP substantially reduces the incidence of bitter pit and prevents scald.

Preparation of fruit for market

To increase farm gate returns there are several key operations in preparing fruit for market:

1. **Separation sorting** - removal of unmarketable and unsound (reject) fruit as well as material such as twigs, leaves and unattached stems and extraneous material including stones, sticks, debris. This provides the initial guarantee of quality to customers. Mechanical devices such as sizing separators, blowers or flotation may be used.
2. **Segregation sorting** - carried out to place fruit into various categories to suit a particular market and its customers. Sorting can be based on colour, size and appearance. Segregation sorting is usually performed on a sorting line as opposed to a grading line.
3. **Grading** - classifies fruit into quality categories based on grade standards, usually maturity or product quality. Quality control is greater than in separation or segregation sorting. This step provides a guarantee of product quality to customers. It also enables you to build a unique brand, differentiating your product from other competing products.

4. **Packaging** - the various categories of packaging include:

    i. consumer units or prepacking

    ii. transport packaging

    iii. pallets or unit loading (bins)

    Packaging must satisfy several basic objectives:

    - contain the produce
    - facilitate the handling
    - facilitate the marketing by standardising the number of units per pack, weight per pack and quality category
    - protect the produce from:
        - injury (impact, compression, abrasion, and wounds)
        - adverse environmental conditions (temperature, relative humidity)
        - contaminates (dirt, dust, foreign objects, chemicals, etc.).

5. **Labelling and product classification** - provides information to your customers: variety, weight and number of units, quality grade, producers name, area and country of origin. This information is critical for traceability and food safety. Product classification is part of marketing and promoting the product brand. This is achieved through the inclusion of recipes, nutritional value and health benefits, and printed information that differentiates your product from other competing products.

Packaging, labelling and product classification is covered in more detail in Section 5.

Preparation of fruit on farm for market reduces the number of times the fruit is handled before reaching the consumer. It also significantly decreases the chance of contamination and potential damage your produce is exposed to, as well as offering an opportunity to promote your farm produce and build a reliable market reputation, ultimately resulting in greater economic returns.

Quality Standards

To ensure that the quality standards set for export fruit are met, check the export manual and your export agent for information on the target market requirements and customer expectations.

Apples are exported in standard cardboard cartons with a minimum net carton weight of 18 kilograms. Bulk shipping is available where quarantine protocols allow. Arrangements can be made for customers with specific packing requirements.

See Appendix 3 for the Food and Agricultural Organisation (FAO) and World Health Organisation (WHO) International Food Standards CODEX Alimentarius Codex Standard for Apples –CODEX STAN 299-2010. This is available at the FAO Website: http://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FStandards%252FCODEX%2BSTAN%2B299-2010%252FCXS_299e.pdf

This Standard covers the following topics:

- Definition of the produce
    - Provisions concerning quality
        - minimum requirements
    - Maturity requirements
    - Classification
        - Extra Class
        - Class I and Class II
    - Colouring
- Provisions concerning sizing
- Provisions concerning tolerances
    - Quality tolerances
        - Extra Class
        - Class I and Class II
    - Size tolerances
- Provisions concerning presentation
    - Uniformity
        - by diameter
        - by weight
    - Packaging
        - description of containers
- Marketing and Labelling
    - Consumer packages and the Codex General Standard for the Labelling of Pre-packaged Foods (CODEX STAN 1-1985). Available on the website: http://www.fao.org/docrep/005/Y2770E/y2770e02.htm
        - nature of Produce
    - Non-retail containers
        - identification
        - nature of produce
        - origin of produce
        - commercial Identification
        - official Inspection Mark
- Contaminates
    - Codex General Standard for Contaminants and Toxins in Food and Feed (CODEX STAN 193-1995). Available on FAO Website: http://www.fao.org/input/download/standards/17/CXS_193e_2015.pdf

- Hygiene
  - International Code of Practice – General Principles of Food Hygiene (CAC/RCP 1-1969): http://www.fao.org/input/download/standards/23/CXP_001e.pdf
  - Code of Hygienic Practice for Fresh Fruits and Vegetables (CAC/RCP 53-2003): http://www.fao.org/input/download/standards/10200/CXP_053e_2013.pdf
  - Principles for the Establishment and Application of Microbiological Criteria for Foods (CAC/GL 21-1997): http://www.fao.org/input/download/standards/10741/CXG_063e.pdf

Please check the FAO for updates and news on changes to the Codex Alimentarius Commission. The website is located at: http://www.fao.org/news/story/en/item/1024512/icode/

Sorting

Apples are removed from either cold or CA storage for sorting and packing before being sent to market. Fruit is first sorted to remove any deformed, bruised, pest damaged or diseased fruit. The first stage of sorting involves tipping of bins into a hydro handling system where the apples are immersed in water to reduce damage during the bin unloading process, or dry dumping onto a conveyer belt and sorting table to allow unmarketable apples to be removed.

Washing and sanitising

As indicated in the previous section on tipping/dumping, apples are submerged in the hydro dump tanks (wet dumping). If the water temperature is considerably lower than the fruit temperature, water and decay organisms may be drawn into the fruit from the dump tank solution due to hydrostatic pressure. Infiltration of water and organisms is more likely with greater depth of immersion and length of time spent in the dump tank or in the water used to move fruit through the packing lines.

Removal of reject fruit - Separation

Separation of reject fruit usually occurs immediately after dumping and washing. Most packing sheds in Australia use a combination of hand sorting and automated sorting systems. Trained personnel are required for hand sorting; in automated sorting, sensors scan the fruit and unmarketable fruit are rejected. All practices must be in line with Australian Quality Assurance Systems and International Quality Standards as indicated under **Quality Standards.**

Allowing damaged fruit, plant material and/or foreign objects to proceed further will increase costs. This reject fruit, plant material etc., needs to be disposed of without contaminating the packing shed; it can be composted using processes that comply with GAP or best practice standards and used within the orchard or sold for animal feed.

Hand sorting

Hand sorting requires visual inspection of fruit and removal of unwanted produce, and staff need to be trained to identify fruit with deformities, blemishes or pest and disease incidences. Staff usually stand for long periods at fixed height platforms with fruit moving along a conveyer belt in front of them.

Automated sorting systems

Highly sophisticated systems combining built-in weighing systems and digital cameras with software (algorithms) that can differentiate colour, shape and types of deformities, blemishes and pest and disease incidences are now being used to sort apples for export and domestic markets. These systems can now determine internal fruit quality (brix and firmness), internal browning, watercore, breakdown and other internal defects as well as surface defects.

Automated sorting systems using image analysis (optical colour sorters), near-infrared (NIR) and mid-Infrared (MIR) spectroscopy analysis are proving to be highly accurate. These systems are continuing to improve in accuracy, from 82% to 92%. Some sorting equipment using dual-camera imaging (NIR and MIR) is able to determine true defects from stem ends and calyx ends with a 98.8% to 99% recognition rate. However, the cost and performance of these systems has to be evaluated for economic viability.

Waxing

Edible coatings (waxes) are applied to apples to enhance shelf life and to replace the natural protective waxy bloom coating. They extend fruit shelf life by modifying the internal atmosphere, reducing moisture loss, and enhancing appearance. Waxes are applied once the fruit is taken out of storage and prior to packaging for marketing. For further information see **Edible coatings** at the end of this section. Waxes for apples are approved globally including the United States of America (USA), Europe and United Kingdom (UK). The European Food Safety Authority have indicated that the use of carnauba wax on apples as a food additive is not a safety concern. While synthetic waxes are not approved, both carnauba and shellac are approved as food additives in Australia by Food Standards Australia and New Zealand (FSANZ). However, the major fresh food retailers in Australia do not sell waxed apples.

Grading

Apples vary in density, both within a cultivar and between cultivars. This can cause concerns with size counts and weight targets. Generally speaking, lower density cultivars can result in lower pack out target weights and this impacts on haulage charges. Markets require accurate size grades and consistent pack weights and therefore optimisation of your grading systems is crucial to obtain maximum economic returns.

To remain competitive in your target market, regular monitoring of grading systems is essential to ensure grader accuracy. Under-grading can result in loss of customers and possible de-listing or fines; on the other hand over-grading results in reduced financial returns.

Hence, it is vital that quality controllers assess the performance of grading lines and packers on a regular basis. Quality control should be undertaken by sampling and monitoring the performance against set standards at various stages during the packing process. In addition product quality should also be recorded at the beginning and end of each packing line run. As a guide, some quality controllers suggest that 3% of the total product packed should be visually inspected to ensure the up-to-date customer specifications are met. A final quality control inspection should be undertaken on fruit quality (blemishes and marks), weights, label compliance, traceability information and pallet stacking and pack security.

Minimising bruising in the packing shed

The impact stresses placed on fruit during picking, transport, dumping, handling and packing can lead to fruit tissue experiencing bruising. Bruising occurs when the tissue experiences an impact well beyond its bruise threshold. The relationship between impact energy and tissue stress (bruising) has been researched for apples.

The equation is: E= m x h x g.

m = mass of the individual fruit
h = height of fall
g = earth's gravity

Many apples are bruised or crushed at the bottom of the bin in transport to the packing shed due to orchard row and road conditions and the method used to transport the fruit. Most apple cultivars at the bottom of a fruit bin can withstand approximately 1.8kg of static force before bruising of the flesh will occur. Therefore bins should only be loaded to a level less than 1.8kg of static force.

In the packing shed cushioning reduces the impact severity by dissipating the energy through absorption of the energy or by spreading the energy load over a greater surface area.

Fruit tissue strength depends upon how quickly loads are applied to them. Under slow loading, apple fruit are tough and rubbery but under fast loading they are brittle. Other influences on tissue strength are temperature and turgidity (how well the fruit is hydrated). Cold and highly turgid fruit are more brittle and have a greater sensitivity to crushing and impacts.

Research on 'Golden Delicious' fruit of 200g size one day after harvest has shown that approximately 10% of fruit are bruised when dropped from a height of 2mm onto steel. Whilst temperature was found to have minimal impact on bruising, hydration level had a substantial effect. The bruise threshold of 'Delicious' and 'Golden Delicious' cultivars doubled from 9mm to 18mm when fruit were slightly dehydrated – a weight loss of approximately 2%. Therefore determining the optimum threshold for bruise resistance and weight loss is critical to ensure optimum fruit quality. For example, fruit moving at 65 g-force (g's) with a velocity of 0.93 m/s impacting against a side rail can result in some form of bruising as shown in Figure 33.

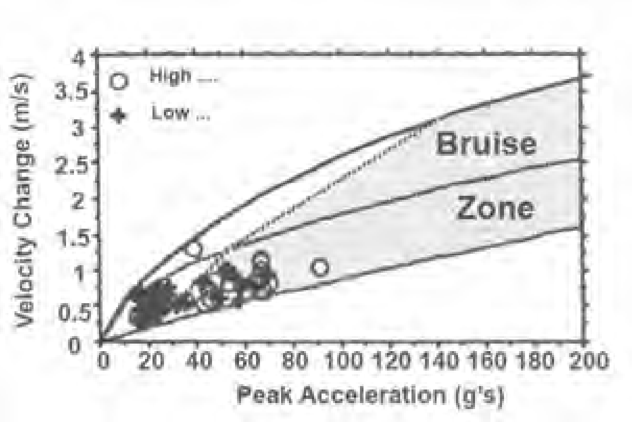


Figure 33. *Bruise height impact chart. Washington State University.*

To reduce the number and severity of impacts it is recommended that cushioning along the packing line be improved. In general:

- eliminate hard supports under belts where fruit drop
- add retarders to ramps
- establish the flow rate of your fruit to its mass on rolling ramps
- reduce elevation changes at each transfer point in the packing line
- avoid fruit flows that allow fruit to roll and hit each other

Research has found that:

- small bruises (less than 6.35mm in size) appear in rotating brush conveyers used for washing polishing and waxing
- large bruises (greater than 6.35mm in size) occurr at other stages throughout the packing line
- lower brush speeds reduce severity of small impacts and apples hitting each other
- lower brush speeds reduce the total number of impacts per fruit

Hence for bruise susceptible cultivars, lowering the brush speed but keeping flow rate even and reasonably fast will reduce bruising.

Cleaning and sanitising programs

Cleaning should encompass:

- transport equipment used in the field and/or packing shed
- containers or bins used for transfer or storage of fruit at any stage of the operations
- the packing shed, including floors, walls, drains, door and window screens
- cool rooms and storage rooms
- air conditioning units
- staff facilities (toilets, lunch rooms, etc)
- packing lines including bin tippers, conveyors, tanks and water flumes, dryers, grading belts/cups/chutes
- storage areas.

Sanitation

Sanitising follows the cleaning process. Sanitisers are designed to significantly reduce the numbers of remaining viable microorganisms and so render the surface safe. They will not kill all microorganisms. General classes of sanitisers that can be used on surfaces and equipment include:

- chlorine agents
- iodine compounds
- quaternary ammonium chloride compounds
- peroxy compounds
- acid anionics
- carboxylic acids
- electrolised water

Apples are one of the longest stored fruit and thorough sanitation of the cold storage facilities, storage bins and liners is essential to reduce the potential of contamination and spoilage. Store rooms, bins, liners, covers and forced air curtains should be thoroughly cleaned and sanitised before use. Cold rooms can be disinfected with a 0.25% solution of sodium chloride and surfaces allowed to dry for several days.

Storage technologies

An apple is a biological living organism and once harvested it continues to mature, ripen and senesce until the living tissue in the apple dies and decays. Whilst the physiological ageing process (maturity, ripening, senescence and decay, respiration, ethylene production and water loss) and the biochemical changes that occur in the apple (conversion of starch into sugars) cannot be completely stopped, the postharvest cold storage of apples increases fruit life.

Energy use and carbon footprint associated with the costs of operating and running storage facilities represents a trade-off between maintaining storage life of the apples and customer/consumer acceptance of the product. Consumers are becoming increasingly concerned about chemical usage, food safety, and on farm production and environmental practices. Temperature, humidity, inhibition of ethylene, ultra-low-oxygen (ULO) control, Dynamic Controlled Atmosphere (DCA) and chemical use have to be carefully weighed up against your target market, customer/consumer requirements and cost benefit to your farming enterprise.

State-of-the-art storage technology cannot transform fruit of sub-optimal quality at harvest into high quality – it can only maintain the quality at the level that it went into storage.

Controlled atmosphere storage

Controlled atmosphere (CA) is used to extend the storage life of apples. However, some apple cultivars are sensitive to chilling injury which develops during storage and with the use of gas mixtures (e.g. oxygen (O_2) and carbon dioxide (CO_2)). These gases are used to regulate the ripening process and lessen the extent of various apple physiological disorders that may develop during storage. CA systems are expensive to install and operate, but apple quality can be easily lost due to inadequate supply chain practices before and after CA storage.

Australian CA storage systems have changed substantially over the last 20 years. Initially controlled ventilation was used with 6-18% O_2 and 3-5% CO_2. Systems were then developed with levels of O_2 and CO_2 reduced to 2-5% O_2 and 2-5% CO_2. Now ultra-low oxygen (ULO) levels are used in modern CA storage systems; these systems maintain O_2 levels at 0.25-0.7% for short periods after harvest, followed by ULO storage levels of 0.8%-1.2% O_2 and 0.5-2% CO_2. Dynamic controlled atmosphere (DCA) is used by some cool store operators. In DCA systems, the O_2 is reduced to the lowest level possible without causing an anaerobic respiration point (ACP) to be triggered, without damaging the fruit physiology. However, this system has the O_2 level above 0.2%. In addition, new technologies where DCA-chlorophyll florescence, combined with ethanol in a dynamic control system (DCS) and respiratory quotient are being used.

Achieving good consumer acceptance of stored apples requires the understanding of apple disorders, especially flesh browning disorder (FBD), or cortex tissue cellular collapse. Research evidence indicates that FBD is a result of CO_2 injury, and it has been suggested the incidence and severity increases with increasing CO_2 concentrations. Research findings also suggest that cultivar, maturity level at harvest, cell size and intercellular spaces, rather than chemical changes within the apple, influence FBD disorder.

As with most fruit, apples change their resistance to various pathways of diffusion of O_2, CO_2 and water vapour when they mature. The skin consists of highly connected cells with very little air space and its resistance changes during maturity. This is one of the primary factors regulating the internal concentrations of gases within the apple. Some apple cultivars (e.g. 'Granny Smith') have relatively few open pores (lenticels) in their skin surface while other cultivars (e.g. 'Delicious') have a substantial number of lenticels. Cultivars with relatively few lenticels are prone to develop off flavours.

The intercellular spaces within the apple flesh generally facilitate the diffusion of gases. As noted earlier, apples have a large internal air space (25-30% of the total volume). This results in considerable gradients being detected in apple flesh. Apples can have a 10 to 20 fold higher flesh gas gradient compared to the skin, creating substantial concentration differences of gases within the flesh. As apples ripen, the resistance to CO_2 diffusion increases and resistance to ethylene (C_2H_2) decreases as the intercellular space fills and their density increases. Therefore the reduction in the ability of CO_2 to defuse out of the fruit increases CO_2 concentrations resulting in an increased chance of FBD injury.

To reduce O_2 levels to the level required for long term storage, CA rooms are usually flushed with nitrogen. However, good air circulation is needed to ensure O_2 concentrations in areas within the room do not drop too low as fruit will start fermenting; bins should be arranged to allow good air movement within the CA room. Cultivars have different sensitivity levels to O_2, so it is crucial to store cultivars with similar sensitivities to temperature, O_2 and CO_2 levels together.

As indicated above, CO_2 requirements of cultivars need to be taken into account as well as O_2. If SmartFresh™ is used to treat fruit, then lower CO_2 levels can be used. CO_2 is removed from rooms by the use of specialised scrubbers (hydrated lime or calcium carbonate), but if the CO_2 levels are too high, browning disorders can occur on the skin and in flesh, making the fruit unmarketable. SmartFresh™ has been found to increase sensitivity to CO_2 in some cultivars.

It is critical to note that temperatures and CA gas mixtures vary with cultivar and geographic locations in which the cultivar is grown.

Studies have shown that FBD can occur in the cultivar 'Pink Lady™' when there is less than 1200 growing degree days (GDD) above10^{o}C between full bloom and harvest. However storing fruit at 3^{o}C can reduce the incidence of FBD. In addition, the radial type of FBD in 'Pink Lady™' occurs when fruit experience growing conditions between 1200-1700 GGD and above 10^{o}C between full bloom and harvest. This fruit is susceptible to CO_2 injury in atmospheres containing high levels (approximately 3%) of CO_2. In 'Braeburn', FBD can be aggravated by elevated CO_2 and depressed O_2 but may also develop in fruit prior to harvest or during air storage.

Cooling rate and rapid CA availability for O^2 pulldown rates are:

- rapid CO_2 pulldown within 3 days;
- slow CO_2 pulldown 5 to 7 days;
- stepwise CO_2 pulldown at 2-3 °C during loading and maintain 2°C at sealing of CA rooms, and 1°C after 2 to 3 weeks of CA establishment.

However, fruit for long term CA it is recommended to use rapid CA, but water-cored fruit should be stored at high oxygen (2-2.5%) to prevent internal breakdown.

Table 2. *(right) Storage periods temperatures, CO_2 and O_2 levels for preclimacteric export apple cultivars.*

Cultivar	Storage Period	Storage temperatures, CO_2 and O_2 conditions
Bravo™	Fruit can be stored for long term with the use of SmartFresh™. Fruit should be precooled to 2-4ºC within 24 hours after harvest.	Fruit can be stored short term at 1.0ºC Optimum long term storage temperature is from 0.0-0.5ºC.
Delicious	Long storage 12 months in controlled atmosphere (CA) as for red spur strains. 3 months is recommended for air storage.	Early research suggested CA storage temperature of 1.0ºC at 3% O_2 and 4% CO_2. However further research suggests the lowest limit for O_2 is 0.85% down to 0.47%. Nitrogen flushing will not control scald when stored in 2% O_2 and 1% CO_2. Rapid cooling rates can be used for air storage, but for CA storage rapid to moderate rates are recommended with O_2 levels of 2-5%. This will reduce the level of internal breakdown.
Envy™	For long term storage it is suggested that a stepwise storage process be used.	Step wise reduction in temperature over 14 days. Delays in implementing CA storage for 21 days using cooling air before implementing < 0.7% CO_2 and 3% O_2 substantially reduced the incidence of FBD.
Eve™	Fruit can be stored up to 7 months.	Storage temperature of 0.5ºC
Fuji	Long term storage and similar to red strains of apples but can suffer from scald. A stepwise cooling for air storage is suggested for storage up to 4 months and slow rate for CA storage for up to 12 months.	Storage temperature of 1.0-0.0ºC for air and CA storage conditions. For CA storage a slow CA 5-7 days reduction of O_2 and CO_2 is used. The greater the maturity level of Fuji apples at harvest the more prone fruit are to internal browning. Fuji apples can be stored at very low O_2 levels, 0.5-1% O_2 with CO_2 levels at <1%. If CO_2 level are held above 3% internal damage can result. Internal chilling damage can occur where watercore is present, especially where fruit are held at 0ºC.
Golden Delicious	Moderate term storage For air storage a rapid cooling rate can be used for 3-4 month storage and rapid CA storage for 8-10 months.	Temperature control should be 1.0-0.0ºC for air and CA storage. For CA storage O_2 levels at 1-2% and CO_2 levels 2-3%. Research findings suggest the lowest limit for O_2 is 0.92% down to 0.45%.
Granny Smith	Long term storage up to 12 months is possible. Air storage is 3-4 months with CA storage from 10-12 months. For air storage a rapid cooling rate can be used but for long term CA storage slow stepwise cooling is used.	Storage needs to be established using a stepwise process down to 1.0ºC with 1.0% CO_2 and 1.8% O_2. Nitrogen flushing will not control scald when stored in 2% O_2 and 1% CO_2 but when stored in less than 1% nitrogen the severity of scald is substantially reduced.
Jazz™	Long term storage requires a stepwise decrease in temperature, however soft scald damage can occur.	Temperature from 3.5-1.5ºC possible scald damage. Storage at 3ºC under normal CA condition avoided effects on apple quality. CA conditions of 2.5% CO_2 and 2% O_2 and ULO (2.5% CO_2 and 1% O_2) have shown good results.
Kanzi™		Kanzi™ has shown high sensitivity to internal browning during CA storage. It is very sensitive to low temperatures and to increased CO_2. When stored at 3ºC Kanzi™ showed substantially less incidence of internal browning. When CA stored in conditions of 0.7% CO_2 a reduction in internal browning was observed. Late harvested more mature fruit have a high sensitivity to internal browning.
Modi™	Limited information on storage times and conditions.	

Pink Lady™	Up to 4 months in air and 6-9 months in CA. Slow temperature rate of cooling is used for both air and CA storage. Harvested at immature stage (surface colour - dull red, background colour score 1 with green colour and starch content score 1-2, full black, sugar 10-11% and flesh firmness above 10kg). Extreme scald risk. Harvested at near mature stage (surface colour - dull pink red, background colour score 2 with more green than yellow and starch content score 2, some clearing in the core, sugar 12-13% and flesh firmness 9-10kg). Prone to scald. Harvested at optimum mature stage (surface colour – pink/red, background colour score 2.5-3.5 with green and yellow blond tinges and starch content score 2.5-3.5, clear areas extend beyond the core, sugar above 13% and flesh firmness 8-9kg). Minimal scald risk. Harvested at ready to eat stage (surface colour – bright pink/red, background colour score 4-5 with green / yellow colour and starch content score 4-5, clear areas extend through the cortex, sugar above 13% and flesh firmness 7-8kg). Harvested at over mature stage (surface colour – red with greasy surface, background colour score 5 with all yellow colour and starch content score 5-6, clear 90-100% of the cortex is clear, sugar above 13% and flesh firmness 6.5kg).	Storage at 3.0°C will prevent the development of FBD, however storage at 1°C will reduce symptoms. Storage at 3.0°C will reduce the period of storage time before quality loss occurs. However, Pink Lady™ can be stored at 1.0-0.5ºC with 1.0% CO_2 and 1.5% O_2. Immature, near mature, optimum mature, ready to eat and over mature stage – pre-cool fruit to 2-4ºC within 24 hours of harvest then maintain at 0.5-0ºC temperature. For CA storage always keep O_2 level at 1.5-2.5% and CO_2 levels at 1.0-2.0%, but ensure CO_2 levels are 0.5% lower than the O_2 level.
Rocket™	Keeps well for 5 months under normal storage conditions and longer periods using CA and SmartFresh™	
Royal Gala	Keeps quite well, with no bitter pit, scald or breakdown occurring.	Storage temperature of 0-1ºC for 2-3 months in air. For CA storage with 1-2% O_2 and 2-3% CO_2 storage life is 5-6 months. Has rapid CA capability. No sensitivity to CO_2 recorded.
Smitten™	Limited information on storage times and conditions.	
Sundowner™	Fruit can be air stored for 4 months and CA stored for 6 months. Harvested at immature stage - surface colour - dull red, background colour score 1 with green colour and starch content score 1-2, full black, sugar below 12% and flesh firmness above 11kg. Some scalding may occur. Harvested near maturity stage - surface colour - dull red stripe, background colour score 2 with more green than yellow and starch content score 2-2.5 but clear in most of the core, sugar below 11-12% and flesh firmness above 9.5-10kg. Some scalding may occur. Harvested optimum maturity stage - surface colour - full red, background colour score 2.5-3 with green/yellow blond tinges and starch content score 2.5-3.5, clear areas just beyond the cortex, sugar above 13% and flesh firmness above 8.5-9.5kg. Minimal scald risk. Harvested ready to eat stage - surface colour – bright red strip, background colour score 4 and starch content score 4-5, with clearing areas extending through the cortex, sugar above 13% and flesh firmness above 7-8kg. No scald risk. Harvested over mature stage - surface colour – red strip, background colour score 5 and all yellow colour and starch content score 5-6 with a 90-100% clear cortex, sugar above 13.5% and flesh firmness below 6.5kg. No scald risk.	Pre-cool to 2-4ºC within 24 hours of harvest and maintain 0.5ºC-0ºC with CA of 1.5-2.5% O_2 and 1.0-2.0% CO_2. Maintain the CO_2 level lower than the O_2 level by 0.5%.

Please note: temperatures and CA gas mixtures vary with cultivar, maturity at harvest and the geographic locations in which the cultivar is grown. Where SmartFresh™ is used please refer to recommendations issued by the distributor.

It is strongly recommended that you carry out your own trials to determine the optimum storage conditions suited to your cultivars and growing environment. To illustrate, peel greasiness can be reduced by SmartFresh™ as well as the use of CA storage for some apple cultivars. In addition, scald incidence is higher in some air stored apple cultivars compared to CA stored apples. SmartFresh™ can have an inconsistent effect on scald in some apple cultivars and internal CO_2 injury can be enhanced by the use of SmartFresh™. Bitter pit may also be intensified and subsequent internal browning can be reduced in some apple cultivars with the use of SmartFresh™.

Temperature control

Refrigeration has long been used to control ripening and prolong storage life of apples by reducing respiration rate. Physiological disorders can be influenced by the environmental regions that fruit are grown in, impacting on optimal storage temperatures. Storage technologies also affect optimal storage temperatures. Research has shown that 'McIntosh' apples can be stored at 0°C air temperature or 2-3°C under CA storage conditions.

Harvested mature apples held at air temperature in a packing shed have greater softening, respiration and water loss rates. Apples stored under these conditions soon become unacceptable to consumers. Apples held at 4.4°C respire and degrade twice as fast as apples held at 0°C; fruit held at 15.5°C will respire and degrade six times faster than apples held at 0°C.

Usually the optimum storage temperature for apples depends on the cultivar and the environmental conditions under which it was produced. Storage temperatures between 0°C to 4.4°C with a relative humidity from 90 to 95% are optimal. In addition, some apple cultivars as moderately susceptible to cold damage or scald and temperatures below 0°C should be avoided. Water vapour added to the air in the storage room through humidifiers will reduce water loss. However, humidity levels that reach near 100% will encourage the growth of bacteria and fungi, causing spoilage. Damaged or spoiled fruit will release ethylene, causing the ripening process to accelerate.

Relative humidity (RH) is usually maintained by minimising any room temperature fluctuations. Variations and rapid changes in RH caused by temperature changes substantially affect fruit quality. The bins in which fruit are cooled need to have sufficient ventilation holes to allow adequate cool air movement. Stacking of bins is critical to facilitate modified room cooling and also for apples packed in cartons. Please note - cultivars that ripen quickly need to be bought down to low temperatures quickly, especially when cool rooms are near capacity.

Forced Air Cooling

Forced-air cooling is where the cool room air is forced through the container by creating a pressure difference between opposite faces of stacks of vented containers. The cold air moves past the produce inside and removes heat rapidly. Cooling is faster and more even through the stacks than traditional room cooling, where air flow is mainly past the outside of the container.

A forced-air cooler can be designed for a new cool room or an existing cool room can be converted to include a forced-air cooler. There are three methods of forced-air cooling:

Tunnel cooling

Tunnel cooling is suitable for cooling even numbers of bulk bins, pallet loads or floor stacks of containers.

A row of pallets (or bins or containers) is placed on each side of an air channel that opens into a plenum (large box) mounted with an auxiliary fan. The same number of pallets must be placed in each row.

A reinforced blind is run over and down the end of the air channel. The air is pulled through the containers into the air channel and back through the plenum and auxiliary fan to the cooling unit. When open top containers are cooled, the top of the containers must be covered either separately or by a full width blind.

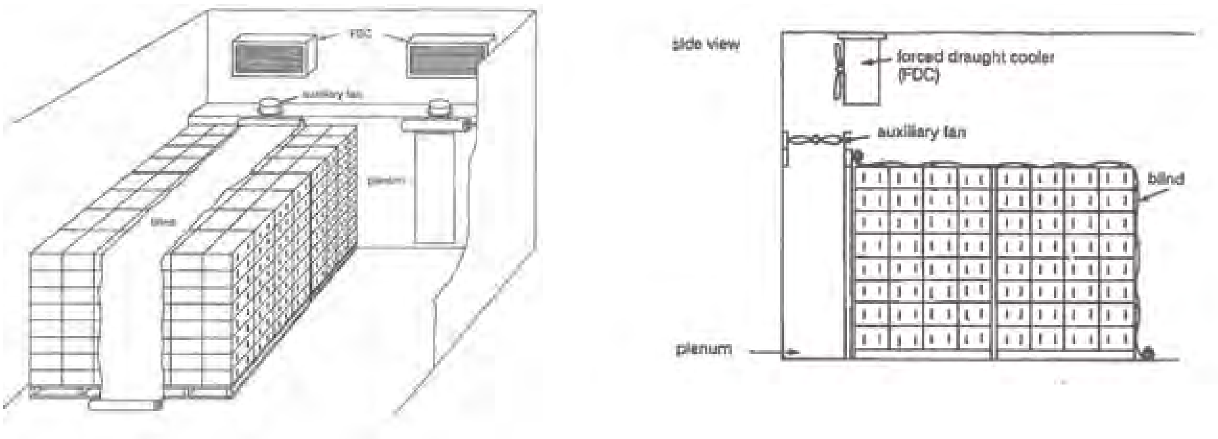


Figure 34. *Tunnel cooling Image Source: Watkins, 1990, Forced-Air Cooling, Queensland Department of Primary Industries.*

Cold wall cooling

Cold wall cooling is suitable for cooling single pallets or stacks of bulk bins and containers. The pallet (or bin or container stack) is placed against an opening of similar width in the plenum. Air is pulled through the containers directly into the plenum and back through the auxiliary fan to the cooling unit. The pallets must only be one deep against the plenum.

For both methods, the auxiliary fan should always be positioned so that the warm air is directed to the back of the cooling unit. The plenum with auxiliary fan can be a fixed structure or a portable box. Multiple openings and fans can be placed in a fixed plenum, with the openings covered when not in use.

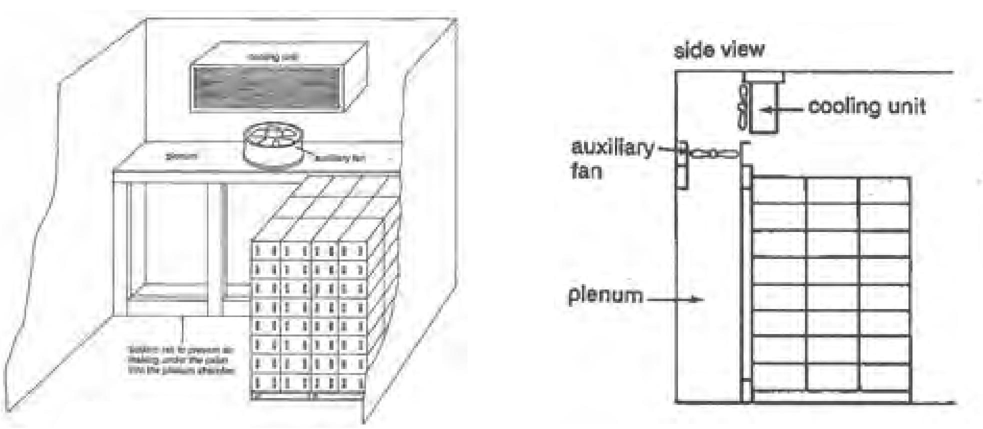
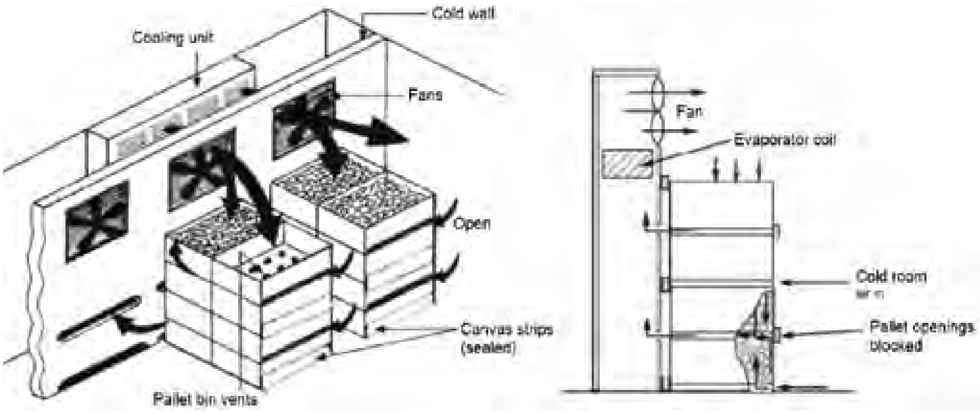


Figure 35. *Cold wall cooling. Image source Watkins, 1990, Forced-Air Cooling, Queensland Department of Primary Industries.*

Serpentine cooling

This system is used where fruit is stored in bins that have ventilated slots in the base. The channels on the underside of the bins (forklift channels) supply the air and return air when stacks of bins are placed against a plenum wall. Bin channels that do not align with the plenum air channel are blocked and plenum air channel slots aligning with the channels in the bins are left open.



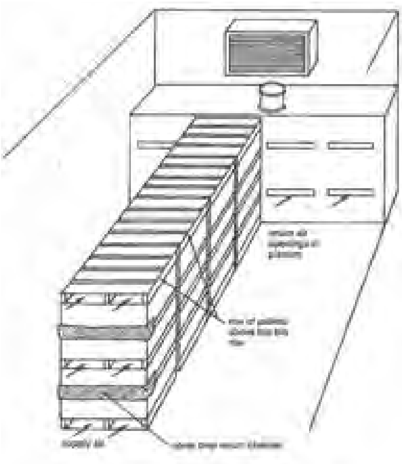


Figure 36. *Serpentine cooling. Image source: 36a http://eagri.org/eagri50/HORT381/lec08.htm and 36b Watkins, 1990, Forced-Air Cooling, Queensland Department of Primary Industries.*

Cooling time

The desired cooling time determines the product load on the refrigeration system and auxiliary fan requirements. This in turn determines the dimensions of the supply and return air channels for tunnel cooling, a factor in calculating room size. A cooling time of 8 to 12 hours is sufficient for cooling apples.

Depth of plenum

The depth of the plenum (front to back) must be allowed for when calculating room dimensions. The plenum has to be of sufficient depth and width to accommodate the fan, clear of any structural supports.

Cooling only or cooling plus holding

If the produce is cooled daily and held for a number of days before dispatch, the design must allow for a holding area in addition to the cooling area. However if cooling and holding in long term CA storage then dedicated CA facilities are needed.

Rapid air movement is required for fast cooling but only slow air movement in needed to maintain the temperature of cooled produce. The cooling unit is placed above the forced-air cooler and the holding area is offset. Another alternative is to have separate cooling and holding rooms.

Rapid air movement is required for fast cooling but only slow air movement in needed to maintain the temperature of cooled produce. The cooling unit is placed above the forced-air cooler and the holding area is offset. Another alternative is to have separate cooling and holding rooms.

Calculating refrigeration load

As a guide, ⅔ of the refrigeration capacity is needed to cool the produce and the remaining $^1/_3$ for the extraneous heat load.

The refrigeration capacity required to cool the product load is calculated as follows:

$$\text{Product load (watts)} = \frac{\text{product weight (kg)} \times (t^1 - t^2) \times 1.29}{\tfrac{7}{8}\text{ cooling time (hours)}}$$

(t^1-t^2) = temperature difference (°C) between incoming product and the cool room setting

⅞ cooling time = time to cool the product to ⅞ of the difference between initial product temperature and the cool room setting.

If the refrigeration capacity is not known when adding a forced-air cooler to an existing cool room, a rough estimate can be made as follows:

Refrigeration capacity (watts) = compressor motor horsepower × 1760, **or**
= compressor motor kilowatts × 2360

The amount of refrigeration capacity available to cool the product load will be approximately ⅔ of the total capacity. Using this estimate, the ⅞ cooling time for a specified amount of product can be calculated with the formula above.

The total refrigeration load is the sum of the product load and extraneous heat loads such as wall load and air change load. The wall load depends on the room dimension and the thickness and type of insulation used.

Calculating air flow requirements

The total air quantity required is determined by the total weight of produce to be cooled multiplied by the air flow rate per unit weight for the chosen cooling time. The containers and produce inside create resistance to air movement through the pallet or container stack. The more containers the air is pulled through, the higher the resistance. This resistance is measured as static head of pressure (mm of water).

The auxiliary fan must not only generate the required air flow but must also operate against the static head created. The auxiliary fan requirement is therefore specified as the required air flow quantity and static head rating. When calculating the required air flow, an additional $^1/_3$ air flow is added to allow for air losses leaking around the containers and the pallets.

Information on air flows and static heads for specified cooling times for a range of produce are contained in the publication "Forced-Air Cooling" by John B Watkins and Scott Ledger (1990), Queensland Department of Primary Industries Second Edition, ISSN 0727-623 and Forced-Air Cooling Systems website http://www.omafra.gov.on.ca/english/engineer/facts/14-039.htm and Washington State University Postharvest Information Network website: http://postharvest.tfrec.wsu.edu/pages/N4I1A

To cool apples in 12 hours in an 8 layer container, the air flow required is 0.5 litres/second/kg and the static head is 2mm of water. If the cooling time is decreased to 8 hours, the air flow required increases to 1.0 litres/second/kg and static head to 10mm of water.

Other storage technologies

In recent years there have been substantial changes in storage technologies for apples with the development of Dynamic Controlled Atmosphere (DCA) and 1-Methylcyclopropene (I-MCP). The economics of these technologies are highly dependent on:

- the scale of operation
- availability of the technology
- ease of incorporation into the existing infrastructure and process
- financial resources to implement these technologies and economic benefit and return to the farming enterprise.

Both of these technologies, DCA and 1-MCP have advantages and disadvantages and these are listed below.

1. DCA/DCS/ULO

Dynamic controlled atmosphere (DCA / Ultra low oxygen (ULO) is reported to be a healthy environmentally-friendly system to keep apples in a fresh state for long periods using low O_2 concentrations. It has been reported to reduce superficial scald. This system operates by monitoring and adjusting O_2 and CO_2 levels to ultra-low-levels (1.2% O_2 and CO_2 2.5% at 1°C), thus limiting the production of ethanol, a precursor to the production of ethylene. If O_2 levels drop too low fruit will go into anaerobic condition and ethanol levels will rise leading to the production of ethylene. Therefore fruit are kept just above the anaerobic state, maximising fruit storage and marketability (firmness and freshness). When using DCA/ULO systems, a very accurate measure of ethanol is required to limit the ripening process. In addition, a dynamic control system (DCS) uses chlorophyll florescence as an indicator of anaerobic stress - when O_2 is reduced to 0.8% and then to 0.2% the florescence will rapidly indicate when fruit start to anaerobically respire and stress due to low O_2. The sensory equipment can easily measure this and then the O_2 is lifted just above the stress level and maintained to avoid damage to the fruit.

Advantages of DCA

- Can be easily installed with existing CA storage facilities. (Note: requires CA rooms with a good seal and little leakage and good control of temperature, humidity, O_2 and CO_2)
- Can alleviate/mitigate against and control superficial scald and physiological disorders
- Chemical free and therefore suitable for organic fruit

Disadvantages of DCA

- Apple fruit suffer a substantial loss of quality after removal from CA storage and also from DCA storage facilities
- To upgrade to DCA facility requires a substantial level of investment, especially for the installation of the computer based systems and sensors
- Storage rooms have to be of high-quality to ensure good high-level-control of O_2 concentrations, otherwise rooms with low lower levels of O_2 control are uneconomical to operate
- Requires operators with sufficient knowledge to understand and interoperate the stored apple responses to O_2 control and concentrations

- Only fruit of uniform maturity and grade standards (no blemishes or damage) can be placed in DCA rooms
- The DCA system is not suitable for small unit based operations and small unit loads.

2. 1-MCP

1-Methyclyclopropene (1-MCP) is an inhibitor of ethylene production; it binds at a cellular level to the sites that produce ethylene and stops the signalling of ethylene receptor sites to produce ethylene. 1-MCP is a gas that is released in sealed rooms from either a powder or tablets (SmartFresh™) under a SmartFresh™ system. 1-MCP is easily applied, active in low concentrations and the effects on ethylene production and respiration substantially improve storage life whilst fruit is stored and transported. Once out of storage and a refrigerated environment ripening occurs normally. 1-MCP has improved the eating quality of fruit, providing consumers with crisp textured fruit with good sugar/acid balance as first found at harvest.

Advantages of 1-MCP

- 1-MCP is applied as gas at very low concentrations and can be applied at any time after harvest or during storage.
- It is possible to incorporate 1-MCP into packaging materials
- It is applied in a sealed room or tent and no computerised or expensive equipment is needed
- Rigorous monitoring by a qualified operator is not required
- Fruit of mixed quality can be treated with 1-MCP as opposed to DCA
- MCP controls some fruit physiological disorders such as superficial scald
- Fruit quality characteristics (texture, sugar and acid) are retained along the cool/value chain until fruit are eaten.

Disadvantages of 1-MCP

- Cost of applying 1-MCP
- May increase the risk of some physiological disorders in some cultivars, in particular where CO_2 regulation can result in damage
- In some situations the modification of handling and process protocols are needed where 1-MCP has been used.

Postharvest treatments

Depending upon target market, marketing plan, cultivar and growing region, fruit can be treated with fungicides to control postharvest diseases. In addition, an antioxidant Diphenylamine (DPA) can be used to control physiological disorders, including superficial scald and carbon dioxide (CO_2) injury. Other postharvest treatments include edible coatings that are applied to fruit during packaging, heat treatments, and microwave treatments.

1. DPA

DPA has proven to be an inhibitor of superficial scald. It is low cost and easily applied as a dip or drench. Concerns of contamination with recycling of dips and drenches have led to new methods of application. DPA prevents superficial scalding by limiting the oxidation that causes cell damage, whereas DCA and ILOS possibly inhibit both scald and oxidation. Therefore, DCA, ULO, ILOS and 1-MCP are alternatives to the use of DPA. DPA has other effects on fruit as it also inhibits the ripening process and internal physiological disorders. However, pre-storage of fruit in air before being subjected to CA storage conditions decreases CO_2 injury; 1-MCP maintains fruit sensitivity to CO_2 injury in some cultivars.

The desired amount of DPA is applied to each fruit using thermo-fogging and aerosol technology. Even though DPA is safe to use the European Commission withdrew authorisation of DPA use in 2009. If DPA is not used additional steps in the process have to be put in place to reduce the risk of CO_2 injury. With the increased use of 1-MCP the use of DPA has increased.

2. Edible coatings

In Australia, both major supermarket retailers have made the decision to sell apples with no added wax. However, apples naturally produce a waxy layer to protect the fruit when growing. This is a natural defence mechanism to protect the apple from moisture loss. Once apples are harvested and cleaned for sale (sanitised) this natural waxy coating is lost. Food grade waxes (carnauba wax and shellac) approved as food additives by the Australian Food Standards Australia and New Zealand (FSANZ) can be applied. These waxes are extensively used with many other food products, such as chocolate confectionary as well as makeup, skincare products (sunscreen), lipstick and lip balms. These wax products are also approved in USA, Europe and United Kingdom. Approximately 85% of apple waxes used in Australia are shellac based.

These waxes can extend the shelf life of fruit by reducing moisture loss and modifying the internal atmosphere within the apple. As indicated earlier, the intercellular spaces within the apple flesh facilitate the diffusion of gases, resulting in considerable gradients being detected in the apple flesh. Apple flesh can have a 10 to 20 fold higher gas gradient when compared to the skin. These edible coatings can act as a delivery mechanism for antimicrobials, texture enhancers and nutraceuticals. Waxes are normally applied when packaging takes place to enhance appearance for consumers. Synthetic waxes are not allowed on organic fruit but carnauba wax and shellac are permitted. However there is some resistance from a select few consumers and considerable amount of mis-information and scaremongering about waxes on fruit has been placed in the media.

Figure 37. *Waxed apples.*

Section 5: Packaging

Packaging has three primary functions:

- distribution requirements
- customer/consumer requirements
- legal requirements.

1. Distribution

Growers and transporters are looking for the best possible product protection, storage and transport cost based on weight/volume. Packaging design will depend largely upon the nature of the product in terms of value, physical composition and durability and variations in climatic conditions.

Conversely, retailers are looking at sales per square metre or linear metre per shelf as a measure of productivity. Therefore, retailers avoid packages that occupy a disproportionate amount of space.

2. Customer/Consumer

Some research has shown that consumers want products and have little interest in packaging per se. However, packaging offers the ability to differentiate your product against competing products in an objective manner. Packaging offers the ability to change sizes, grade quality and volumes and reach consumers with different purchasing powers.

3. Legal

Legal requirements: Identifying volume/weight, grade size and quality to safeguard people's interests. In Australia, health and nutritional information are mandated by Food Standards Australia and New Zealand (FSANZ).

GAP and environmental concerns

Packaging is approximately one-third of the rubbish by weight thrown away. Packaging relies and impacts heavily on our natural resources. Packaging manufacturers are now developing processes to mitigate against environmental pollution as well as greener and biodegradable and re-useable products which are used as part of their marketing strategies.

Packaging from a grower's perspective

In Australia packaging is based on a combination of fruit counts and weight. Packaging can be categorised into three types:

1. Consumer packaging (inclusive of sales, primary, display, or retail packaging). This is packaging that is in contact with the produce or contains the quantity of produce acceptable to consumers for purchase.
2. Transport packaging (inclusive of box or secondary packaging). This is used to facilitate the handling of fresh produce and provide effective protection of produce in transit.
3. Unit packaging (inclusive of distribution, bulk, container, distribution or tertiary packaging). This is used for bulk shipments of fresh produce.

In recent years, to reduce waste and styrofoam packaging, environmentally sustainable systems using plastic crates and containers were introduced. There has been a move from single-use to returnable packaging and packaging that can be recycled. The transport packaging systems currently being used can be grouped in to several sub categories:

i. Single-product-use: to carry one type of product only

ii. Multi-product-use: to carry many different products

iii. Single-loop-pool system: to carry products in returnable transport packaging between supplier and one customer

iv. Multi-loop-pool system: to carry products in returnable transport packaging between the suppler and many customers

v. Open-loop-pool system: complex system designed to carry many products in returnable transport packaging between many suppliers and many customers (this system is sometimes operated by a third party).

Most horticultural produce, and in particular fruit ready for market, is composed of large numbers of small units of similar size which must be moved in amounts conveniently handled by one person.

The basic aim of packaging is to:

- Protect product from damage:
  - cuts, punctures, impact (shock, vibration, shaking, rubbing), bruising and compression (deforming, crushing, squeezing or squashing)
  - mould, pest, disease – impregnated liners, coatings, waxes, modified atmospheres
  - contaminants - dirt, dust, microbes, chemicals, foreign objects (e.g. rocks, glass, metals)
  - light, moisture and free-water damage
  - animal and human damage
- Protection during transport to end user:
  - physical - movement and over-stowage
  - ambient temperature and humidity changes, keep the product cool through ventilation, limit respiration and build-up of gases that degrade product quality and shelf life.
- Enhance temperature, gases and humidity and atmosphere control to maintain product quality and increase shelf life
- Enhance storage, handling, transport and cooling methods – e.g. road, water and air transport
- Uniformity with transport containers,
  - air - unit load devices (ULD's) e.g. AKG, AVE, AVN, AKN, PAP, APG, PMC, AA2 AAP, PKC)
  - sea freight (20' and 40' dry cargo containers, 40' dry cargo super high container, 20' reefer container (FINSM), 20' bin, 20' and 40' bolster platform, 20' and 40' flatrack, 20' and 40' open top container. Refrigerated sea freight containers and ISO containers
  - road freight for fresh produce containers - there are too many container types, shapes, sizes, and packaging materials to document
- Identification
  - product – description, (cultivar, size, grade/class, weight (gross and net), number of units, brand, country of origin, harvest and use by date, dimensions and name and address of grower, packer and receiver

○ shipment, transaction details

• Point of sale - marketing, branding

○ package design, marking, branding to enhance the appearance of the product and differentiate the product for its competitors

○ provide information about the products functional, nutritional and health benefits

○ protect the product from theft. Produce theft occurs regularly and packaging that protects individual units from being stolen is a must as this can represent a significant cost to the grower.

○ recyclability and biodegradability - a growing number of markets have waste disposal restrictions of packaging materials

○ cost effective packaging

Pre-packaging / consumer / unit packaging

Prepacking is where the produce is weighed or the required number of pieces reaches the consumer in the same container in which it was prepared in the packing shed. The number or weight is usually based on what a family can consume during a certain time period.

Prepacks can be either moulded pulp or expanded polystyrene trays wrapped in shrink-wrap plastic film or moformed PVC trays. There are a large variety of colours, shapes and textures of packaging materials that play an important role in improving the attractiveness and appearance of the product being presented to the consumer. Information can be added to these packs to increase consumer awareness of your brand and differentiate your product from competing products.

Figure 38. *Consumer packaging for Rockit Apples and Tasmanian Tiger Fuji apples.*

Image Sources: The Packer website: www.thepacker.com/article/seeking-new-sales-channels-rockit-apples-climb-washington-state; APAL website: http://apal.org.au/apple-pear-production-tasmania/)

Transport Packaging

This is for transporting fruit to markets. This type of packaging usually consists of fibreboard, wooden or plastic containers/crates/boxes or bags weighing from 4kg up to 20kg. Heavier packs are difficult to handle and need specialist equipment to move and are classified as container or pallet packaging.

Transport packaging must be easy to handle, stackable by one person and have the appropriate dimensions to fit into transport vehicles (road freight trucks, air freight containers, and shipping containers). Ideally, materials should be biodegradable, non-contaminating and recyclable. Repeat use packaging should be easy to clean and dismantle to reduce volume during the return trip. It should be capable of withstanding handling, climatic conditions where the product is marketed and ultimately where sold. Packaging should also meet count and weight specifications without being overfilled and causing damage to the produce.

The use of inserts, dividers and immobilisers help to prevent the fruit from being damaged. These immobilisers may also reinforce the container. Wood, wool and shredded paper have been used to immobilise the product in the container.

Figure 39. *Transport packaging for Australian apples.*
Image source: Visy, website: www.visy.com.au/packaging/cardboard-boxes/fruit-and-produce-boxes/

Unit load packaging or transport containers, pallets/bins etc.

Internationally, pallets have become the main unit load packaging method. Dimensions conform to sea freight and air freight containers, trucks, forklifts, storage facilities etc. When pallets are used, handling steps in the distribution chain are eliminated. Pallet unit loads are secured with a mesh tensioning cover, corner posts and horizontal and vertical strapping. Large single unit containers that are used for other fruit crops are not suitable for apples.

Types of packaging and materials

Solid or corrugated cardboard container types (carton or boxes) can either have a fold over (closing the top of the carton) or slip-on top (made separately). Most of these types of cartons/boxes are manufactured and supplied in collapsed form, (that is pre-cut and flat) and are put together by the grower or packer. In some cases the construction of these boxes requires the fixing of interlocking tabs, sometimes with glue or staples.

These boxes can be manufactured in a wide range of sizes, designs, strengths and are clean and light weight. Even greater strength can be added to the carton/box by waxing to prevent moisture from softening the fibreboard. Waxed cartons/boxes are particularly useful in the tropics where moisture absorption is a common occurrence due to large changes in temperature and humidity between storage rooms.

Most modern trays are constructed from Xitex cardboard. Xitex board consists of two flutes joined at their tips with liners on both sides. The perfect alignment of the flute tips means extra strength, at the same price. Boxes made by this technology are lighter, stronger, smoother, smaller and squarer.

Boxes and liners available in Australia include:

- Three layer box and lid, 15kg (482mm x 313mm x 250mm) capable of being stacked at 590 boxes per pallet.
- Four layer box and lid, 18kg (492mm x 322mm x 265mm) capable of being stacked at 800 boxes per pallet.
- P6 box and lid 12kg (569mm x 377mm x 148mm) capable of being stacked at 780 boxes per pallet.
- LifeSpan® liners range from 12-14kg and 20kg carton liners and bags at 2, 4 and 9kg.
- Apple trays P12 liners come in a range of sizes from 22, 25, 27, 28, 30, 32, 33, 35, 38, 39, 41, 42A, 42B, 45, 49, 51 and 54.

Labelling

1. Labelling for export

For information on labelling for export, refer to *Export manual for apples: a guide to exporting apples* by Ian Cover, Rajendra Adhikari, Sally Bound and Robert Nissen.

2. Fruit stickers

Most growers use stickers to highlight either their brand name or when to eat the fruit. Stickers should not be placed on the apex of the fruit or used to hide blemishes. Stickers should be applied so that they can be read from the labelled end of the box.

Retailers in Australia are required by law to display the country of origin and label where food was grown, manufactured or packaged. It is regulated through Standard 1.2.11 under the Australia New Zealand Food Standards Code (the Code). However, some apple fruit may already carry an individual sticker indicating the country of origin of the food. Both Price Look Up (PLU) code and Global Trade Item Number (GS1) identification number enable electronic reading at point of sale or upon receival at markets, warehouse or distribution centres. The Trade Item Implementation Guide (GDSN 3.1 Release 25.3 Ratified, Sept, 2017) document can be downloaded from the following website:

https://www.gs1.org/docs/gdsn/tiig/3_1/GDSN_Trade_Item_Implementation_Guide.pdf

GTIN is used for the unique identification of trade items worldwide within the GS1 system. The GTINs used to identify different fresh produce items across the supply chain and fresh produce industry are: GTIN-12 (UPC), GTIN-13 (EAN-13) and GTIN-14 (GS1-128).

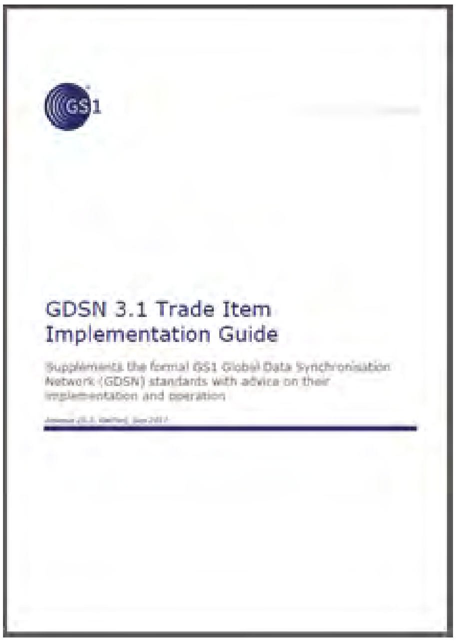


Figure 40. *GDSN 3.1 Trade Item Implementation Guide and GS1 Barcode User Guide booklets.*

3. IFPS PLU code

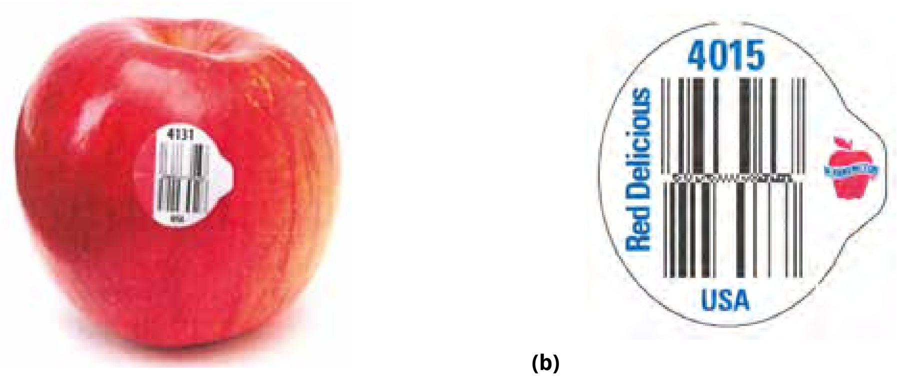
IFPS PLU is short for International Federation for Produce Standards Price look up code and codes contain 4 or 5 digits. The 4 or 5 digit number is used for loose or bulk produce such as fruit. For organic apple the prefix '9' is inserted in front of the 4 digit conventional code (3000 or 4000). The organic range 93000 - 94444 was developed for organically grown produce. It is anticipated an additional range of numbers (84000 – 84999) will also be used for organic grown items. In addition, retailers can designate their own number for items that do not have a standard PLU code. Below in Table 3 is a list of some apple PLU codes from the IFPS.

Table 3. *Price look up (PLU) codes for apple cultivars*

PLU Code	Cultivar/Variety	Size	Revision Date
3010	Cripps Red	Small	1999-12-31 00:00:00
3301	Cripps Red	Large	2002-10-16 00:00:00
3613	Fuji	All Sizes	2016-06-20 19:04:02
4133	Gala	Small	1999-12-31 00:00:00
4135	Gala	Large	1999-12-31 00:00:00
3285	Golden Delicious	Extra Large	2000-01-01 00:00:00
4020	Golden Delicious	Large	1999-12-31 00:00:00
4021	Golden Delicious	Small	1999-12-31 00:00:00
3005	Golden Delicious Blush	All Sizes	1999-12-31 00:00:00
3071	Granny Smith	All Sizes	1999-12-31 00:00:00
4193	Granny Smith	Small	1999-12-31 00:00:00
3468	Honeycrisp	Small	2016-03-01 20:53:20
4145	Jonagold	Small	1999-12-31 00:00:00
4147	Jonagold	Large	1999-12-31 00:00:00

PLU Code	Cultivar/Variety	Size	Revision Date
4151	Jonathan	Large	1999-12-31 00:00:00
3072	Lady	All Sizes	1999-12-31 00:00:00
3284	Red Delicious	Extra Large	2000-01-01 00:00:00
4015	Red Delicious	Small	1999-12-31 00:00:00
4016	Red Delicious	Large	1999-12-31 00:00:00
4112	Regent	Small	1999-12-31 00:00:00
4172	Rome	Large	1999-12-31 00:00:00
4173	Royal Gala	Small	1999-12-31 00:00:00
4174	Royal Gala	Large	1999-12-31 00:00:00

Data Source: IFPS data base



(a) (b)

Figure 41. *(a) Fruit Sticker on Apple. Image source: Daily Dose Blog, What do those codes on stickers of fruit and some veggies mean, website: http://www.bewell.com/blog/what-do-those-codes-on-stickers-of-fruits-and-some-veggies-mean/*
(b) GS1 DataBar for USA Red Delicious Apple. Image source: Produce Marketing Association website: www.pma.com/Content/Articles/2014/05/GS1-DataBar

In the future, if IFPS approves the move to more specific size option (two or three sizes) for fruit the currently assigned code will migrate to the number used for the most common size determined by industry.

For example, in the USA, currently there is one size for 'Belchard' apples: PLU code 3339. Should a request for size differentiation be approved by IFPS the PLU code 'Belchard' apples 3339 will refer to 100 size and smaller and a new PLU code will be issued for 'Belchard' apples large (88 size and large).

Further information on IFPS PLU Codes can be obtained from the following website: http://www.ifpsglobal.com/Identification/PLU-Codes/PLU-codes-Search and the IFPS PLU User's Guide shown in Figure 42.

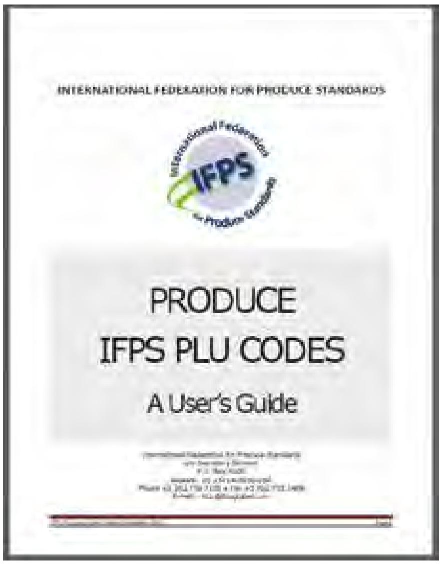


Figure 42. *IFPS PLU User's Guide*

Barcodes do not indicate the country of origin of the product. This information should be displayed in writing on the label as shown in Figure 41.

4. QR Codes

Quick Response Codes (QR Code) are now becoming very popular. These codes are a two-dimensional (2D) Matrix Bar Code that can be read by new smart digital technology units (Smart Phones and Camera Phones) that are linked to a website. These codes are read across two-dimensions (length and width) and are a powerful marketing tool. Customers can scan these QR labels which may provide the customer with information about the enterprise, its location, product type, enterprise contact information and information about the nutrition of the product etc. For example, the major retailers in Australia are implementing a process using QR codes where their customers can "Meet the Grower" program.

Figure 43. *QR Code on consumer packaging of Australian apples offered for sale in Australia.*

5. Point-of-Sale and Consumer Items

Global Trade Item Number (GTIN) and Retail item use a 13 digit number. The barcode for the retail items includes EAN-13 vertical bar pattern and spaces encoding the GTIN 13 number as shown below in Figure 44. Before printing your barcode, do a digital check to ensure that the number to be generated is correctly calculated.

This information can be obtained from the following website: http://www.gs1au.org/resources/check-digit-calculator

Bar Coding: These are data carriers that are commonly used allowing automatic data capture. New data carriers are GS1 DataBar, GS1 DataMatrix and now EPC/FRID (Electronic Product Code/ Radio Frequency Identification Technology). Barcodes may also include other information on packaging.

Figure 44. *An example of a barcode (not to scale).*

The GTIN-13 and EAN-13 barcodes can include information such as expiry date, batch/lot number, serial number etc.

However, fruit are regarded as Variable Measure Trade Items and may be sold in random amounts for a fixed price per unit quantity at Retail Point-of-Sale (POS). Fruit are either marketed in store by the retailer or by the supplier. Currently there is not a global solution for Variable Measure Trade Items sold at point of sale (POS), but standards are being developed for these items in the Fresh Food area. Growers can apply for labels and barcodes to GS1 Australia and a 13 digit number VMN-13 (Variable Measure Number) can be used.

Rules relating to GTIN can be viewed at the GSI website http://www.gs1.org/1/gtinrules and the GS1 Australia website http://www.gs1.au.org

Positioning of these barcodes is in the lower right quadrant of the pack with a quiet zone around the barcode and edge rule. Edge rule stipulates that the bar code must not be closer than 8mm or further than 100mm from any edge of the package/container.

Figure 45. *An example of a GLN in a GS1-128 barcode. The application Identifier (414) indicates that the GS1 Application Identifier data field contains the Global Location Number (GLN) of a physical location. The GS1 Company Prefix may be of variable length. The Serial reference varies on length as a function of the GS1 Company Prefix Length. The Digit is calculated on digit number used to ensure data integrity.*

6. GS1 DataBar Code for Loose Fresh Produce

A GS1 DataBar Stacked Omni-Directional is now used and represents Global Trade Item Number (GTIN) as a compact square barcode. Enterprises utilising GS1 standards ensure product traceability and food safety standards are being met, but it also enables business processes to be streamlined along the supply chain. An example of a GS1 DataBar code is provided below in Figure 46.

The height and width dimensions are shown to allow for legibility. Encodes of the GTIN 13, 12 or 8 data fields can be displayed on the label, but filler zeros must be added to make up the standard 14 digits required.

10.15mm

14.01mm

(01) 0 93123 4567890 7

Figure 46. *GS1 DataBar Stacked Omi-directional sticker. Image source: GSI Australia website, www.gs1au.org*

Understanding labelling

GS1 barcodes are now administered by GS1 Australia. This system is used in Australia and internationally by all major food retailing enterprises. This system allows customers and suppliers to keep track of sales, ordering and pricing information electronically. It also enables product traceability and provides information on food safety issues. GS1 allows enterprises to track, trace, deliver and pay for goods across the supply chain, anywhere in the world. GS1 Australia has a full list of GS1 Identification Keys. The barcodes associated with the GS1 system are used to encode the GS1 Identification Keys, facilitating data collection and information exchange between trading partners. GS1 also includes EAN (European Article Numbering) and UPC (Universal Product Code) barcodes.

The Global Trade Item Numbers (GTIN) are used as identification and assigned to every different variation of a product (size, style, grade, colour, dimensions, weight, etc.) within the GS1 system.

This information accompanies the GS1 Barcode and is represented by GS1 Application Identifiers (AIs). A complete list of AIs can be found at http://www.gs1au.org Furthermore, GS1 System clearly makes the distinction between numbering and barcoding even though they go together.

Numbering: The GS1 System provides Identification Keys for different applications. The application determines the number used. There are nine GS1 Identification Keys that indicate trade items, logistic units, shipments, consignments, locations, documents, service recipients, individual assets and returnable assets.

7. Grower/packers identification labelling

For traceability a trade description must appear on one end of the carton/box or package in letters 5mm high. It must indicate the following information:

- name and address of the packer
- the word 'apple'
- cultivar
- grade
- count and or weight
- for supermarkets, PLU (Price Look Up) numbers.

Further information may also be included such as:

- a brand name
- grower number
- ICA and QA (Quality Assurance)
- date of packing.

It is highly recommended that growers read the guides:

- Traceability for Fresh Fruits and Vegetables Implementation Guide Issue 1:
- GS1 Fruit & Vegetable GTIN Assignment Implementation Guide Release 2.0.1, Ratified, June 2016.
- GS1 Fresh Fruit & Vegetable Labelling Consumer Units Guideline, Release 1.0.1, Ratified, July 2015.

Figure 47. *Traceability for Fresh Fruits and Vegetables Implementation Guide (left) and GS1 Fresh Fruit & Vegetable Labelling Consumer Units Guideline (right).*

Brands and branding

Australian growers use different brand and label names. Growers whose brands are associated with higher fruit quality will generally receive better prices for their fruit. This can be as much as $4-5 per box or higher.

Augmenting your product through a brand is an effective strategy to enable customers and consumers to distinguish between your product offerings and those of competing products. The building of a brand is relying on your customers to repeat purchase. It also allows customers to avoid repetition of unsatisfactory purchases. Therefore your brand is a collection of your customers' expectations, perceptions and past experience based on your product properties and attributes. Brands take time to develop but are easily destroyed with one lapse in product quality. Research on consumer habits and fruit purchases show that if a customer or consumer has a bad experience they will not purchase for 6 weeks and a second bad experience they will not purchase for the rest of the season.

Research has found that consumers expect generic brands to be of lower quality and price. The major retailers in Australia have developed their own generic brands to expand their grocery market share. Supermarkets have upgraded their product quality specifications and are using these brands as a means of enhancing their store image. These generic brands are stripped of their expensive packaging and promotion costs and are priced just below the more expensive brands.

Transportation

All participants in the supply chain want to deliver the best quality produce to their customers. All transporters/ shippers and consignees should be aware of the maturity indices, temperature, chill requirements, gas and exchange rates, cold sterilisation requirements, and quarantine issues for horticultural produce.

For quarantine issues, protocols and agreements between the Governments and Quarantine bodies of the exporting and importing states/countries should be fully understood.

There are many codes of practice that have been established for handling fresh fruit and vegetables for shippers and road transportation. These cover aspects such as temperature and ethylene management, handling and safety, sanitary requirements, packing of cartons and containers etc. Some relevant codes are:

- Code of practice for the road transportation of fresh produce.
- Code of practice for handling fresh fruit and vegetables in refrigerated shipping containers for Australia exporters.
- The Australian Food Cold Chain Logistic Guidelines 2013.
- Code of Practice for packing of Cargo Transport Units (CTU's).

The importance of a good cool chain

A cool chain is a temperature-controlled supply/value chain. Maintaining the cool chain is the responsibility of everyone who handles fresh produce, from producers to retail sales people. A break in the chain, or breakdown in temperature control at any stage, could impact on the final quality of the product.

There can be up to 20% loss of value of product during shipment. Up to one out of every 10 shipments can result in poor product quality out-turn on arrival. Produce is a living, breathing commodity. Once separated from its plant it continues to live on its own resources and produces energy in the form of heat and gives off carbon dioxide. This leads to:

- ripening
- weight loss
- softening
- colour and texture changes
- physical degradation, including bruising
- attack by rots and moulds

In the case of the Australian supply chain, apples can be moved at least 21 times, involving 9 or more players, and exposing fruit to 15 or more breaks in the cool chain.

Compared to the domestic supply chain the air and sea export chains have more steps, players and cold chain breaks (Table 4).

Table 4. *Players and breaks in a cool chain (Government of SA).*

Item	Domestic	Export air	Export sea
Steps	22	40	33
Players	9	22	22
Cool chain breaks	15	21	18

For apples, the ideal cool chain temperature for sending to domestic markets would be 5°C. These fruit temperatures would be obtained in the cool room on farm before road transport to distribution centres.

Planning and strategies to maintain cool chain

Post-harvest temperature management begins with planning the harvest and field handling. Harvesting when temperatures are too high can cause the produce to rapidly lose quality. Fruit should not be subject to more than 0.5% weight loss between harvest and beginning of cooling. Therefore, most growers harvest early morning to prevent exposure to excessive heat after harvest. Critical points in the supply chain for export markets with risks to the product quality through maintaining the cool chain, and food safety risks are illustrated in Figure 48. Careful planning and strategies need to be put in place to reduce and eliminate risks.

Temperature effects on rate of deterioration

The apple cool chain should be a unified, unbroken, smooth movement of the fruit from the production site through the various processes and facilities (storage, sorting, grading, packaging, handling and transport) to market. Any change in optimum storage temperature and relative humidity can have a substantial impact on product quality, shelf life and consumer acceptability. Any weakness or break in the chain substantially affects the integrity of the product.

The rate of deterioration of perishables increases two to three-fold with every 10°C increase in temperature. Temperature has a significant effect on how other internal and external factors influence the commodity, and temperature also dramatically affects spore germination and growth of pathogens.

Many service providers have little or no influence on other service providers in the cool chain and any lack of communication between providers can compromise the integrity of the apples being exported. In addition, breakdowns in the cool chain have an additive effect on produce and these can result in increases in fruit respiration, ethylene production, water loss due to high vapour pressure deficit between the apples and storage air. Once the exported apples have broken their hibernation state and are placed back under ideal conditions rarely do the apples return to their initial respiration state. The weight loss due to the water loss that has occurred cannot be regained. These potential breakdowns in the cool chain can affect the supply chain and ultimately marketing plans.

During transfer heat can have a substantial effect on fruit. Heat may come from:

- other product stored with the fruit during transfer and storage
- direct and reflected solar radiation and heat transferred through the container insulation
- types of handling systems and transfer vehicles utilised.

Because cool and supply chains utilised for export of fruit consist of many service providers, communication, timely implementation of process and practices, and a good understanding of practices to handle and store apples is crucial for a successful cool and supply chain. The complexity of the cool chain is shown below in the diagrammatic representation of a small and medium apple enterprise that enlists the assistance of a packer to pack their fruit for export (Figure 48) and a small and medium apple enterprise who conducts their own packaging and export to the desired target market (Figure 49).

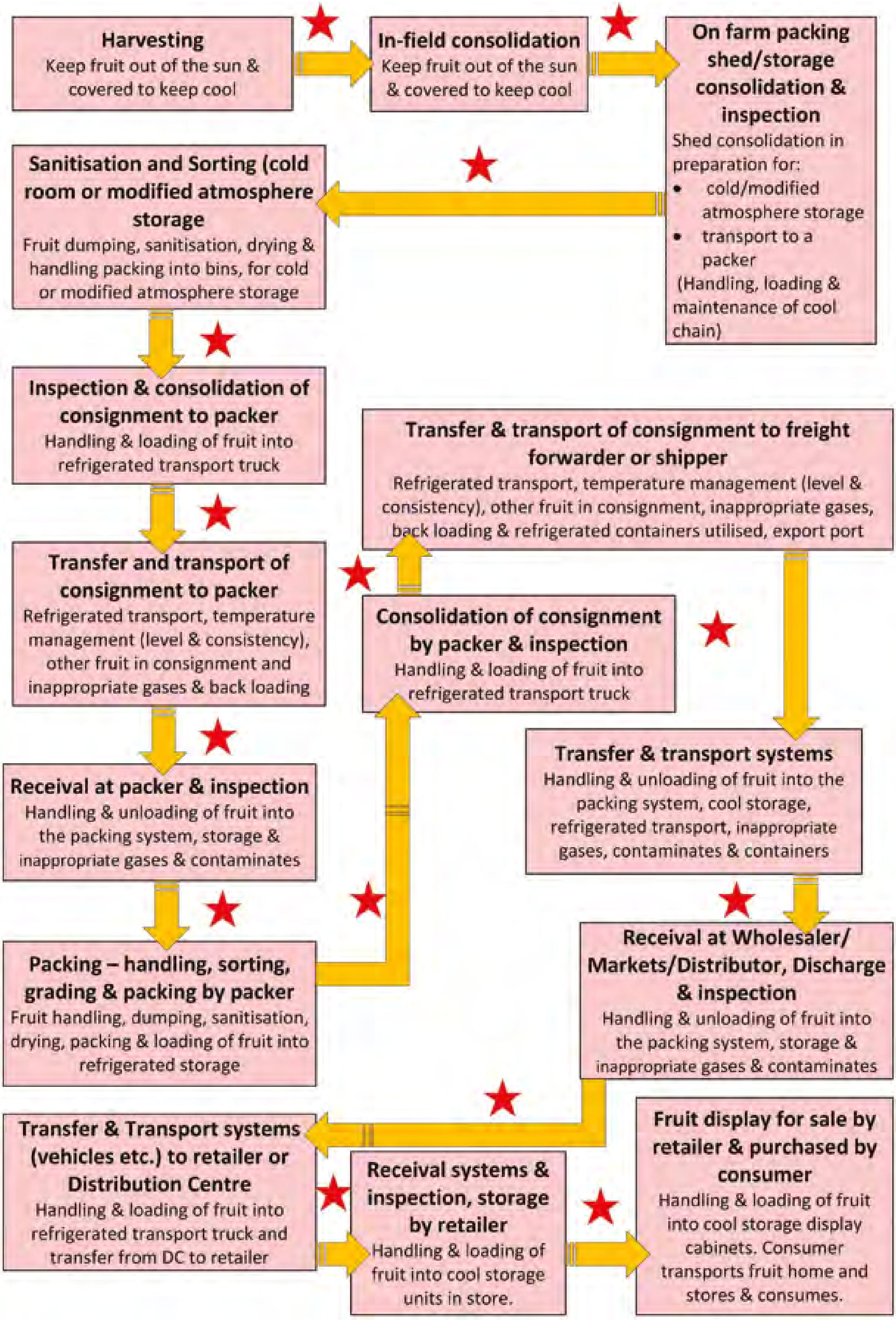


Figure 48. *Diagrammatic representation of the critical points in an apple export cool chain using a packer.* ***The stars represent essential cool management periods for maintenance of product quality & food safety risks. Stars also identify control points that potentially need addressing.***

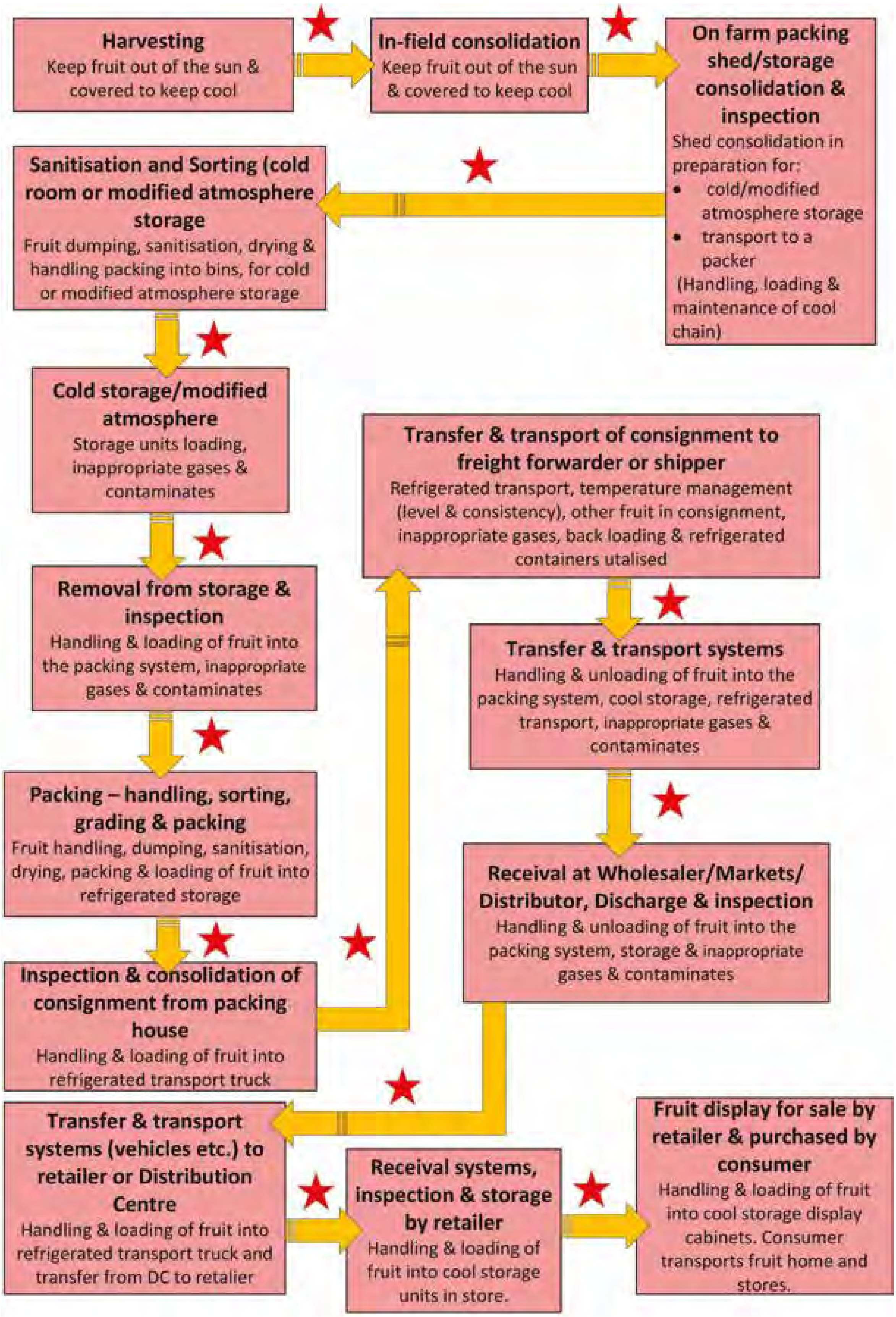


Figure 49. *Diagrammatic representation of the critical points in an apple export cool chain undertaken by the enterprise.* ***The stars represent essential cool management periods for maintenance of product quality & food safety risks. Stars also identify control points that potentially need addressing.***

Reducing temperature damage - field and packing shed

Other methods to protect product from damage caused by temperature are to:

- make frequent trips between the field and packing shed where cool rooms are located
- pack into light coloured containers to reduce heat build-up
- cover containers with lids in the field and keep containers out of the direct sun; if short field storage is required apples must be shaded. Remember the shade cast by a tree moves with sun during the day
- ensure bins are covered in the field and during their removal and transport to the packing shed
- begin cooling as soon as the product arrives at the packing shed
- consolidation facilities that allow apples to be handled in a temperature-controlled environment are essential to maintain the cold chain
- sealed controlled temperature loading docks to load transport vehicles will minimise temperature fluctuations
- where temperature controlled loading docks are not available, load trucks directly from cold store under shaded areas.

Compatibility with other products

Ensure products to be packed together are compatible. In an ideal situation, a container should be loaded with only one type of product.

If products must be loaded together the following matters must be considered:

- sensitivity to ethylene – remember apples are very sensitive
- odours
- off-flavour production/sensitivity

Ethylene producing fruit include: ripening avocados, bananas, papaw, tomatoes, custard apples, passionfruit, rockmelons, honeydew melons, pears, stone fruit, figs or guavas.

Fruit and vegetables that do not produce ethylene can be transported with apple provided the transport temperature is within the recommended range.

Monitoring temperature

Temperature should be monitored at all major points in the cool chain. Use data loggers throughout the cool chain. Electronic thermometers should have a resolution of 0.1°C and be capable of measuring temperatures in the range -5°C to +45°C with an accuracy of ±0.5°C; when measuring a temperature of 0°C, the calibrated accuracy should be ±0.2°C.

Temperature records covering the whole period from the time of harvest to the time of export should be kept. Records should be kept of the cooling rate achieved in each cool room.

To obtain reliable produce temperatures, the sensing probe must be inserted into the flesh of the produce; pre-cool the probe before use by inserting into another sample of fruit.

Produce temperature will vary in packages within the one pallet, and from pallet to pallet, depending on the air circulation in the cool store and the stacking density of the pallets. Produce must be chosen from a number of pallets and at varying packing height locations to obtain temperature variability information.

To obtain an independent record of temperature throughout transport, a self-contained, single-point temperature recorder may be placed in the container. The preferred location for the recorder is in the second package down, at the door end near the centre of the load, and clearly marked with some form of highly visible marking to ensure retrieval on discharge.

If the recorder is placed on top of the load or attached to the ceiling, the recording will not represent produce temperature but will give information on the performance of the refrigeration unit. Alternatively, a multi-point recorder may be used with temperature sensors placed in the produce as well as in the air.

The recorder on the refrigeration unit on older units records the temperature of the return air, but some newer units record the temperature of the delivery air. The accuracy of the recording depends on the care taken during the pre-trip calibration and on any consequential rough handling (e.g. container roughly handled).

In-store management

The cool chain should be maintained from the grower to the supermarket store.

Handling and transport

1. Stacking and palletising

To prevent spoilage of product through dampness, water or fungal infection, it is best to place packaged product on wooden pallets. This also improves ventilation and cooling of the packaged product and moving the product using hand trolleys, trolley jack or fork lifts.

Pallets are normally column stacked with the same tray counts in each column. Normally there are 8 columns per pallet with 16 tray layers high, giving a total of 128 trays on the pallet.

When stacking containers, be sure to align them properly. Whenever possible, stack them so that corner matches corner on both the cartons and the pallet.

Most of the strength of corrugated fibreboard containers is in their corners, so an over-hang of only 2cm will decrease stacking strength by 15 to 34%. A well-aligned stack of cartons has the strongest stacking strength possible.

2. Strapping of pallets

The cartons can be supported with pallet corners and strapping. Please note that Woolworths and Coles will not accept pallets stacked using metal or plastic pallet corners.

Three straps are required with:

- bottom - around the second bottom layer
- top – around the second top layer
- middle – around the middle layer.

Pallet wrapping using plastic could be used instead of pallet strapping provided air flow is not adversely affected as increased ethylene concentrations may trigger ripening.

Netting allows the product to breathe and allows air movement through pallets, as well as stabilising movement of products during transit.

3. Stacking patterns for pallets

Produce transported in cartons should be stacked to allow adequate air circulation throughout the load. Figure 50 illustrates loading of containers. Pallets or other supports should be used to keep the cartons out of direct contact with the floor and walls.

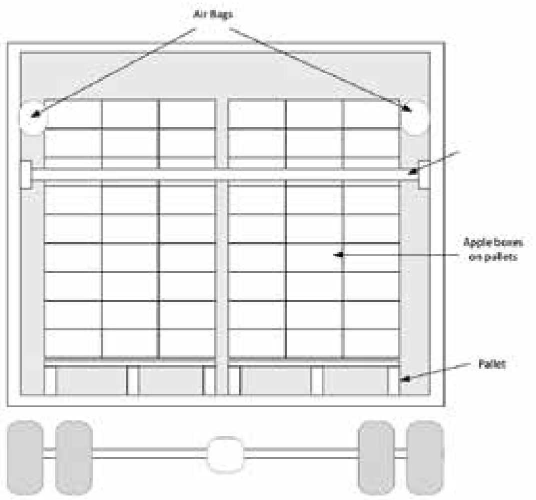


Figure 50. *Loading of cartons and pallets for transport showing bracing to stabilise loads.*

When cartons of various sizes must be loaded together, the larger, heavier containers should be placed on the bottom of the load. Parallel channels should be left for air to move through the length of the load.

4. Bracing the load

There should always be a void between the last stack of produce and the back of the transport vehicle. The load should be braced to prevent shifting against the rear door during transit. If the load shifts, it can block air circulation, and fallen cartons can present great danger to workers who open the door at a destination market. A simple wooden brace can be constructed and installed to prevent damage during transport.

5. Transport trucks

Breaks in the cool chain, such as during loading or unloading of trucks or packing of warehouses, mean that the cool product will warm up. Warming of only a few degrees can be enough to cause the respiration rate of the product to rise and the oxygen within modified atmosphere (MA) bags to fall below the recommended level.

If the oxygen level falls too low then anaerobic respiration can be initiated. If this happens alcoholic off flavours develop within the product, making it unmarketable. There is always a risk/benefit when using MA packaging, particularly when a low oxygen atmosphere is providing the benefit.

Effective precooling before loading is essential for reliable transport of apple. Select your carrier with care and then instruct them as to how you want your product handled, especially as to minimum carrier storage times (both at origin and at destination) and to the vehicle type.

Refrigerated trucks and reefer containers are not designed to pull cargo temperatures down - essentially they maintain cargo temperature. A truck or container should not be used to try to cool fruit down. At best it can only reliably maintain fruit at the loading temperature.

During loading and unloading, the load should spend as little time as possible in non-refrigerated conditions, at most 30 minutes. Ideally the loading and unloading platforms should be refrigerated. Good air flow during transport is essential to prevent the heat transfer from outside the vehicle/container warming the fruit. Travelling at night or early morning reduces heat load on a vehicle that is transporting the product.

Ensure the truck has a working bulkhead and the pallets are stacked so that cold air does not short circuit around the front of the vehicle/container. For example do not leave a gap between the front of the truck and the first pallet as some of the cold delivery air will go directly to the air intake without passing over, around or under the pallets.

When transporting product:

- pallets should be braced or strapped to prevent boxes from leaning against the side walls or rear doors of the vehicle. Air inflated pillows are convenient and very effective
- do not obstruct air flow with pallet separators that touch the ceiling, side or floor of vehicle
- keep trays on pallets to minimise handling
- restrain loads to minimise movement
- use improved or specialised vehicle suspension
- use refrigerated or insulated vehicles
- keep trays away from truck walls/doors to reduce heat conduction from outside.

Minimise ALL transit times, especially non-cold chain delays at holding points, including:

- packing centre
- carrier's depot
- container packing depot
- container terminal.

There are many instances of carriers and/or drivers loading trucks and then holding in their depot (country/city) without refrigeration. This has led to goods being delivered to container packing depots at unacceptably high temperatures (pulp temperature on delivery in excess of 25°C), resulting in loss of quality and consequent rejection.

Relative humidity is not usually controlled in refrigerated transport trucks. However if, humidity is added, then absorption by fibreboard containers can occur causing a weakening of packages. Product moisture loss also occurs, reducing product quality and shelf life. Therefore, the use of modified atmosphere bags will reduce moisture loss.

Section 7: Quality Assurance

A holistic approach should be developed encompassing all levels of the supply chain - from the farm to the consumer's plate. Food can become unsafe at any point along the supply chain. Food regulations and their enforcement designated by governments, retailers (supermarkets) etc., and their appropriate implementation including infrastructure, testing, processes and procedures along the chain and at the local level are necessary to ensure quality and food safety for the consumer.

Basic principles of GAP and codes such as **Codex Alimentarius Commission and Code General Principles for Food Hygiene** apply to growers, packers, handlers, transporters, wholesalers, distributors, vendors and retailers and food service personnel.

On-farm environmental issues can severely impact on food safety as well as the environments that the produce passes through along the supply chain to the consumer. Food safety is paramount in the eyes of the consumer, followed by value for money and quality.

There are six key principles when trying to deliver a product that is safe and quality assured to the consumer:

- remove any product that does not meet the consumers requirements
- eliminate any hazards to the produce in the field when possible
- keep your produce clean and protected from contamination
- avoid any possible forms of contamination
- minimise product deterioration and possible growth of microorganisms
- use only safe clean raw materials and facilities (water, packaging, transport, air, etc.)

To help you understand the food production system or supply chain, modelling the chain enables you to quickly capture critical components of the chain. Once you have the structural model describing all steps and operations (flow chart) you can then undertake various supply chain analyses such as:

- product flows; effective logistics and distribution channels (a model showing where your product is sent and volumes moved)
- technical, operational, efficiency and performance evaluation
- product quality analysis and monitoring against key performance indicators (KPI's)
- market security (volume and price)
- food safety and security analysis against KPI's (delivery of a safe product)
- economic and monetary analysis; monetary flows; (KPI's such as determining marketing margins, marketing costs, net margin and gross margins, transactional costs and equity considerations)
- competitiveness of the chain (KPI's e.g. market share)
- Information and communication (KPI's quality, quantity, timeliness, efficiency and effectiveness)
- chain relationships (business to business (B2B)) and effective value sharing relationships
- consumer and market satisfaction (KPI's matching products to consumers and market segments).

Understanding quality assurance

Quality assurance (QA) is a term used to describe all the practices that give a business and its customers confidence that the product will consistently meet specified food safety and quality standards. In Australia, growers of all horticultural produce are now required to have a QA system in place. Most QA programs incorporate HACCP processes. Training in QA is available. A brief description of the most commonly used QA programs used by Australian growers is presented below. Critical control point is a point or a set of steps implemented within a quality assurance procedure, process or scheme to prevent and eliminate food safety risks, threats, exposures and hazards and includes chemical, biochemical, microbial and physical hazards.

Food safety

A food safety hazard is any chemical, biological, or physical substance or property that can cause fresh fruit and vegetables to become an unacceptable health risk to consumers.

Food safety hazards can be acute or chronic:

- acute is where an immediate health response occurs as a result of contamination
- chronic is where the accumulation of a contaminant results in a delayed health response.

Application of food safety processes and procedures will:

- protect consumer health:
    - consumers expect that food is safe to eat
- allow market access:
    - retailers are requiring suppliers to implement food safety systems right back to the farm
    - governments are introducing regulations to minimise the risk of food safety hazards occurring in both local and international trade.

The significance of the outbreaks of food safety issues is now widely publicised. Food-borne disease outbreaks associated with fruit and vegetables are a relatively small percentage of all food-borne disease outbreaks, but the number of cases is increasing. Food safety is a growing issue globally with a series of food poisoning and disease outbreaks and fatalities occurring on all continents in recent years associated with fruit and vegetables.

Food safety outbreaks are increasing due to several factors such as:

- global trade and particularly where the product is sourced
- changes in the distribution system (time and distance the product has to travel)
- new products – e.g. fresh cut salads that are more susceptible to microbial contamination
- new production and preservation technologies
- new food types – for example, pre-cooked food
- organisms with different levels of virulence
- introduction of new operations and management practices into geographical areas (animal farming in the immediate vicinity etc.)
- immunological changes among population segments, a greater proportion of the population are more susceptible to infectious diseases.

When food safety management fails, outbreaks often occur and costs can be significant. For example:

- Consumer health – outbreaks have a direct effect on human health through a range of intestinal illnesses such as gastroenteritis and diarrhoea and non-intestinal illnesses such as pre-mature labour and still-births, or even kidney and brain infections that are fatal.

- Economic – economic consequences affect not only individuals but their families, companies, industries, governments and society.

Table 5: *Hazards associated with food safety.*

Category	Description
Individuals	• medical care costs • missed work and lost wages • expenses for carers • time wasting
Companies	• complaints and product rejections • extra cost of corrective actions • penalties and class action law suits • loss of reputation • loss of customers and market access
Industries	• loss of consumer confidence in product • decline in sales
Governments	• loss of foreign revenue • costs of disease investigations, surveillance and risk assessment studies • monitoring of emerging issues • quarantine procedures
Society	• loss of productivity • provision of medical care services

Categories of food safety

There are 3 categories/types of food safety hazards:

- chemical
- biological
- physical

1. Chemical hazards

Harmful chemicals at high levels have been associated with chronic illness and death. Studies in Europe, China and India have found on occasions pesticide residue levels and other chemical contaminants including nitrates and heavy metals in some fruit and vegetables to be well above maximum residue limits (MRL). Globally , countries regularly review the use of pesticides, developing improved production practices (farmer training and implementation of integrated pest and disease management systems) and implementing tighter regulations on the sale and use of pesticides to reduce and ensure minimal pesticide residue levels exist in fruit and vegetables.

Chemical contaminants in fresh fruit and vegetables may be naturally occurring or may be introduced during production and post-harvest handling.

Table 6: *Chemical hazards and causes of contamination*

Hazard	Causes of contamination
Pesticide residues in produce exceeding maximum residue limits (MRLs)	• pesticide not approved for target crop • incorrect mixing • withholding period not observed • equipment faulty or not calibrated • pesticide in soil from previous use • dumping or accidental spillage of pesticide into soil or water source
Non pesticide contamination – lubricants, cleaners and sanitisers, paint, refrigerants, vermin control chemicals, fertilisers, adhesives, plastics	• inappropriate chemicals used for cleaning and sanitation • oil leaks, grease, paint on equipment in contact with produce • residues in picking containers used to store chemicals, fertilisers, oil, fuel • spillage of chemicals (lubricants, cleaners, vermin control chemicals) near produce and packing materials
Heavy metal residues (cadmium, lead, mercury) in produce exceeding maximum levels (MLs)	• continued use of fertilisers with high levels of heavy metals • high levels of heavy metals in soil naturally or from previous use or leakage from industrial sites
Natural toxins – allergens, mycotoxins	• unsuitable storage conditions – for example, storage of potatoes in light
Allergenic agents	• Traces of a substance, but not plant foods, that causes a severe reaction in susceptible consumers – for example sulphur dioxide used to prevent rots on grapes

2. Biological hazards

Biological hazards are caused by living organisms, in particular microbes. Microorganisms, or "microbes" are so small they can only be seen through a microscope. Microorganisms are found everywhere in the environment.

Fruit and vegetables contain a dynamic and diverse mixture of microorganisms. The produce we handle daily may contain as many as 100,000 organisms per gram as normal inhabitants that do not affect the health of consumers. There are three classes of microorganisms in relation to food safety:

1. Beneficial: act on food to produce desirable quality characteristics such as aroma, texture, microbiological stability – e.g. lactic acid bacteria for making cheese.
2. Spoilage: spoil the food by producing undesirable quality characteristics such as softening and bad odour and flavour – e.g. fruit rots.
3. Pathogenic: affect consumer health – illness is either caused by the microorganism itself growing inside the human after eating (infection) or by toxins produced by the microorganism in the food before eating (toxicity).

Pathogenic microorganisms are mostly found on the outside of fresh fruit and vegetables but some can get inside the plant tissue. The most common types of pathogenic microorganisms are:

- bacteria
- parasites
- viruses
- moulds

Bacterial

Bacteria are the most common cause of food-borne illness. The number of bacteria that must be present to cause human illness varies with the organism, but in general the risk of illness increases in proportion with the number of pathogen bacteria ingested. In order to reproduce, bacteria require adequate nutrients and appropriate environmental conditions such as humidity, oxygen and temperature. Bacteria can grow rapidly in a very short time. Under ideal conditions, , one bacterial cell can generate over a million cells in approximately 7 hours, but we often use temperature, atmosphere and humidity to stop bacterial growth.

Pathogenic bacteria that have been linked to contamination of fresh fruit and vegetables are:

- *Salmonella* species
- *Escherichia coli (E. coli)*
- *Shigella* species
- *Listeria monocytogenes*
- *Clostridium botulinum*
- *Bacillus cereus*
- *Staphylococcus aureus*
- *Yersinia enterocolitica*

Bacteria such as *Listeria monocytogenes*, *Clostridium botulinum*, *Bacillus cereus* can survive in the soil up to 60 days or even longer depending on temperature and moisture conditions. Produce contamination can be caused by soil contact with the edible part of the produce either directly or through dirty containers and equipment.

Other bacteria such as *Salmonella* sp., *E. coli*, *Shigella* sp., and *Campylobacter* sp. reside in the intestinal tract of animals and humans. They can contaminate fruit and vegetables through animal manures, contaminated water, presence of feral animals in the growing area, and humans handling produce.

Parasites

Parasites are organisms that live in another living organism, called the host. They are unable to multiply outside animal or human hosts but can cause illness with only a low number of organisms. Fruit and vegetables can act as a vector to pass a parasite from one host to another – animal to human or human to human. Cysts, the dormant phase of parasites, can survive and remain infectious for up to seven years in the soil – for example *Giardia*. Water contaminated with faecal material, infected food handlers and animals in the field or packing shed can be vectors for contamination of produce with parasites. Parasites most commonly associated with contaminated fruit and vegetables are:

- *Cryptosporidium*
- *Cyclospora*
- *Giardia*
- *Helminthes*

Viruses

Viruses are very small and unable to reproduce outside of a living cell and do not grow in or on fruit and vegetables. However produce can act as a vector to pass viruses from animals to humans or between humans. Low numbers of surviving viruses on produce can cause illness. Viruses that have been passed onto humans through contaminated produce are:

- Hepatitis A
- Norwalk virus and Norwalk-like virus.

Sources of contamination from pathogenic microorganisms include:

- animal manure
- water
- soil
- sewage effluents, soil, or water, contaminated by human or animal faeces
- dust carried by air from
  - animal enclosures and yards
  - transport vehicles
- immature compost containing animal faeces
- humans
- animals

3. Microbial risk categories

The risk of contamination of fresh fruit and vegetables from pathogenic microorganisms varies with the following factors in Table 7.

Table 7: *Factors affecting pathogenic microorganisms and risk of contamination for fruit.*

How the produce is grown	Produce grown in or close to the ground (carrot) has a higher risk than produce grown well above the ground (apple). Where water quality is poor, produce grown in frequent contact with water has a higher risk – for example hydroponic production.
The type of produce surface	Produce with a large uneven surface (lettuce) has a higher risk than produce with a smooth surface (apple).
How the produce is consumed	Produce that is eaten raw (leafy vegetables) has a much higher risk than produce that is cooked (potato). Produce with an edible skin (apple, grape) has a higher risk than produce with an inedible skin (banana, orange).

Fresh fruit and vegetables can be categorised according to their risk of microbial contamination using the factors as indicated in Table 8.

Table 8: *Fresh fruit and vegetables categories and risk of microbial contamination*

Risk category	Description	Examples of produce
A	Produce can be eaten uncooked, without peeling and washing if it is: • grown in or close to the ground, or • in frequent contact with water.	leafy vegetables carrot mushroom strawberry sprouts
B	Produce can be eaten uncooked if it is: • grown off the ground, or • is protected by a skin that can be eaten or used for meal preparation.	broccoli cucumber apple orange tomato melons
C	Produce can be eaten uncooked if it is: • grown off the ground, or • is protected by a skin that is not eaten or used for meal preparation.	banana papaw lychee mango rambutan pineapple
D	Produce typically eaten cooked.	beetroot chinese water chestnut eggplant potato sweet corn

It is essential that staff handling produce be instructed and trained on how to identify potential risks, reduce those risks and eliminate any form of contamination. One critical risk is personal hygiene and the display of signs throughout your farm and facilities is needed to remind personnel of their responsibilities.

4. Physical hazards

Physical hazards are foreign objects that can cause illness or injury to consumers. Contamination can occur during production and postharvest handling. Types of physical hazards include:

- glass
- wood
- metal
- plastic
- soil and stones
- personal items – jewellery, hair clips
- other – paint flakes, insulation, sticks

Table 9. *Possible physical contamination hazards.*

Hazards	Examples of produce
Foreign objects from the environment – soil, stones, sticks, weed seeds	• Harvesting of ground crops during wet weather • Dirty harvesting and packing equipment, picking containers, packaging materials • Stacking of dirty containers on top of produce
Foreign objects from equipment, containers, buildings and structures – glass, wood, metal, plastic, paint flakes	• Broken lights above packing equipment and areas where produce is exposed • Damaged picking containers, harvesting and packing equipment, pallets • Inadequate cleaning after repairs and maintenance
Foreign objects from human handling of produce – jewellery, hair clips, personal items	• Careless or untrained staff • Inappropriate clothing

Quality assurance and food safety in Australia

In Australia, processes have been designed to reduce risks and manage the factors affecting product quality and food safety along the horticultural supply chain. The majority of Australian growers and processors already have food safety schemes on their farms and/or in their processing facilities. Food Standards Australia New Zealand (FSANZ) estimates approximately 75% of Australian growers are covered by quality assurance schemes. Most growers and packing sheds in Australia are accredited to third party audited internationally recognised quality assurance systems such as:

- HACCP
- SQF 2000,
- Globalgap

or nationally recognised systems such as

- Freshcare™
- WQA (Woolworths Quality Assurance)

1. HACCP

A HACCP system is based on a food safety risk assessment that identifies and controls food safety hazards (microbiological, chemical and physical). What is HACCP?

- **H** = Hazard
- **A** = Analysis
- **C** = Critical
- **C** = Control
- **P** = Point

HACCP Certification is conducted against the accepted Hazard Analysis and Critical Control Point (HACCP) principles and guidelines as outlined by the Codex Alimentarius, CAC/RCP 1-1969, rev. 4-2003. All QA programs incorporate HACCP protocols.

HACCP is all about risk management. It is about a systematic technique or process designed to:

- Identify and rank the importance of hazards
- Determine the critical control points (CCP) needed to control the probable hazards
- Establish critical limits for each process step needed to contain and manage hazards

- Establish a system to monitor control of the CCP's
- Establish the corrective actions to be taken to prevent potential hazards
- Establish verification procedures that monitor and determine the validity of the system and its ability to contain, manage and control potential hazards
- Establish documentation and record keeping procedures, processes and systems that monitor and detail corrective actions that support the verification procedures.

One of the main reasons for implementing a documented food safety system is to demonstrate to your customers your willingness and ability to supply safe, quality food all the time.

Major supermarkets are now going all the way with Quality Assurance, and using it as a tool to advertise. Another reason is litigation: should a grower or anyone involved in your food supply, be found to have contributed to a food borne illness outbreak, the grower is liable for prosecution. A documented HACCP food safety system will enable you to show you took all reasonable precautions to make the product and the process safe. A documented HACCP food safety system will also give you access to markets previously unattainable.

2. SQF - SQF 1000 and SQF 2000

The SQF (Safe Quality Food) Program is a leading global food safety and quality certification program developed in 1994 and now owned by the Food Marketing Institute (FMI).

The program is designed as a food safety program based on the systematic application of Codex HACCP principles and guidelines but includes quality to assure customers that a management system is in place to deliver Safe Quality Food that meets both their own and regulatory requirements.

The program has two standards based on the type of food supplier:

- SQF1000 - Primary Producers
- SQF2000 - Food Manufacturing and Distribution

These Standards are recognised by the Global Food Safety Initiative (GFSI) and provide a link between primary producers, manufacturers, distributers and agents. They are also recognised by retailers and food service providers around the world who require HACCP food safety and quality management systems of their suppliers.

3. GlobalGAP (formerly EurepGap)

For growers exporting to Europe and other countries, the internationally recognized QA system is GlobalGap. GlobalGap is a common standard for farm management practice created in the late 1990s by several European supermarket chains and their major suppliers.

GAP is an acronym for Good Agricultural Practices. The aim was to bring conformity to different retailers' supplier standards, which had been creating problems for farmers. It is now the world's most widely implemented farm certification scheme. Most European customers for agricultural products now demand evidence of GlobalGAP certification as a prerequisite for doing business.

Like most QA systems, the GlobalGAP standard was developed using the HACCP guidelines published by the United Nations Food and Agriculture Organization, and is governed according to the ISO Guide 65 for certifications schemes. Unlike other farm certification schemes, it has definitive rules for growers to follow, and each production unit is assessed by independent third party auditors. These auditors work for commercial certification companies who are licensed by the GlobalGAP secretariat to conduct audits and award certificates where merited.

4. Freshcare™

Freshcare™ is an on-farm assurance program, established and maintained to service the Australian fresh produce industry. Freshcare™ is currently the largest Australian on-farm assurance program.
The foundations of the Freshcare™ Program are the user-friendly Codes of Practice and detailed training support materials. The Freshcare™ Codes describe the practices required on-farm to provide an assurance that fresh produce is safe to eat, has been prepared to customer specifications and legislative requirements; and has been grown with care for the environment. More details can be found at the Freshcare™ website: http://www.freshcare.com.au/

The Freshcare™ Code of Practice Food Safety identifies good agricultural practices required to:

- identify and assess the risk of food safety hazards occurring during land preparation, growing, harvesting and packing of fresh produce
- prevent or minimise the risk of food safety hazards occurring
- prepare produce to customer specifications
- identify, trace and withdraw/recall produce
- manage staff and documentation
- review compliance

5. QA systems for Australian Supermarkets

- All major retailers have in place systems to ensure produce will only be purchased from suppliers who can guarantee food safety under a food safety quality management system based on Hazard Analysis and Critical Control Point (HACCP). As most fruit is currently supplied to retailers through produce wholesalers (agents and merchants in the major metropolitan produce markets), these wholesalers will have to meet the HACCP requirements. In turn, growers supplying them will be required to meet certain food safety standards and become approved suppliers. It is likely that, in time, other quality issues and price look up numbers (PLUs) will also be required as conditions of approved supplier status.
- Growers supplying supermarkets such as Woolworths or Coles must have implemented an acceptable QA program to meet the standards set by these supermarket chains. For example, Woolworth's standards are set out in Woolworths Quality Assurance Manual (WQA version 7), which incorporates HACCP processes. Growers supplying Woolworths will be audited every 6 months. More details can be found at their website: http://www.wowlink.com.au
- Coles have also implemented a Coles Supplier Charter and Food Manufacturing Supplier Program. Details can be found at their website: http://www.supplierportal.coles.com.au/csp/wps/portal/web/Home

Critical points for food safety

It is possible to break down your orchard model into processes and then into sub-process. These process models (represented as flow diagrams) show where inputs interact within your system. The flow diagrams of the processes are broken down into key steps. Shown below are the various flow diagrams of processes for growing and packing. The diagram shows where potential food safety hazards can contaminate your crop.

Holistic approach to GAP and Quality Assurance and Food Safety

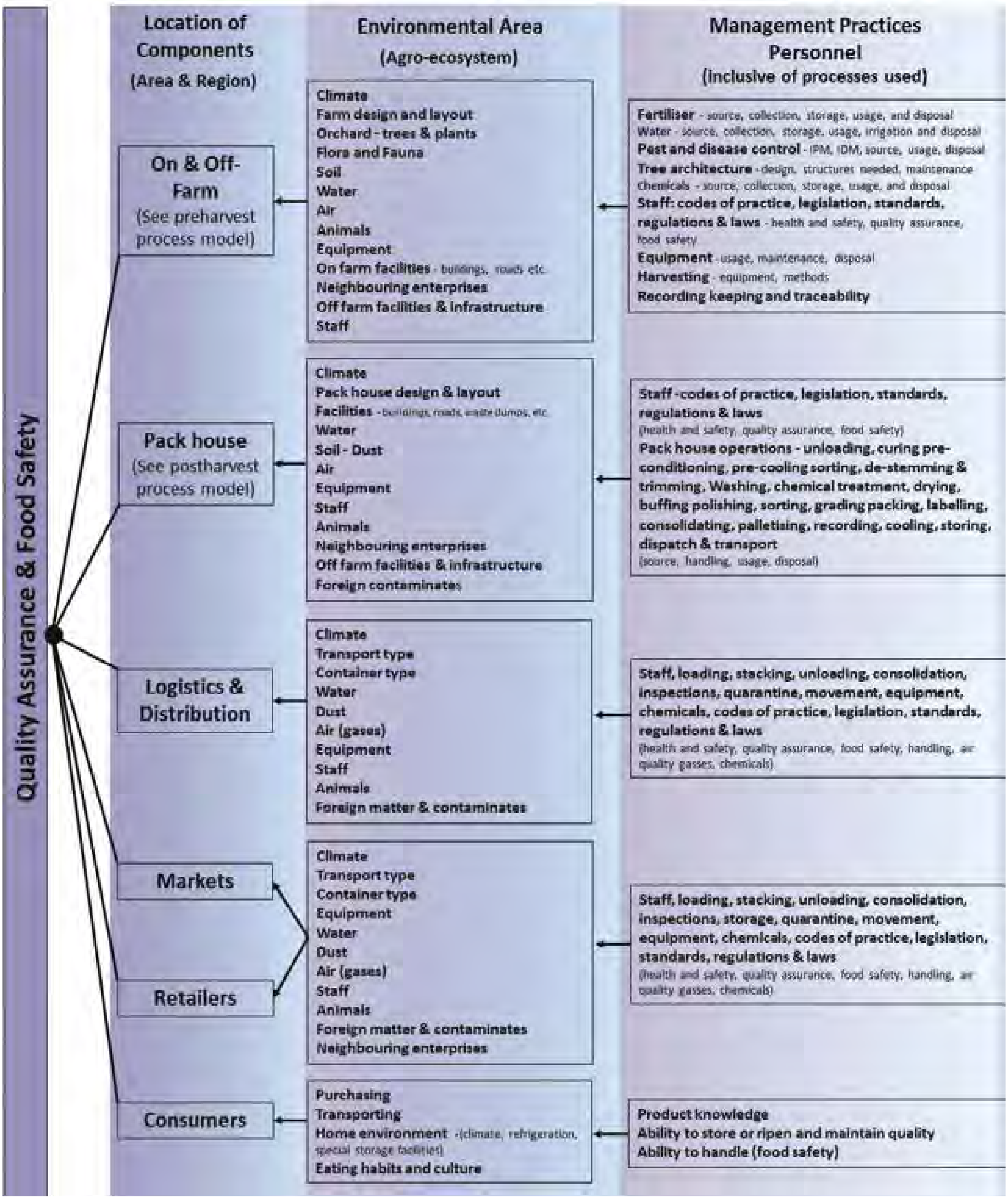


Figure 51. *Modelling a holistic approach to GAP, Quality Assurance and Food Safety.*

Supply Chain Map of Australian Apple Export

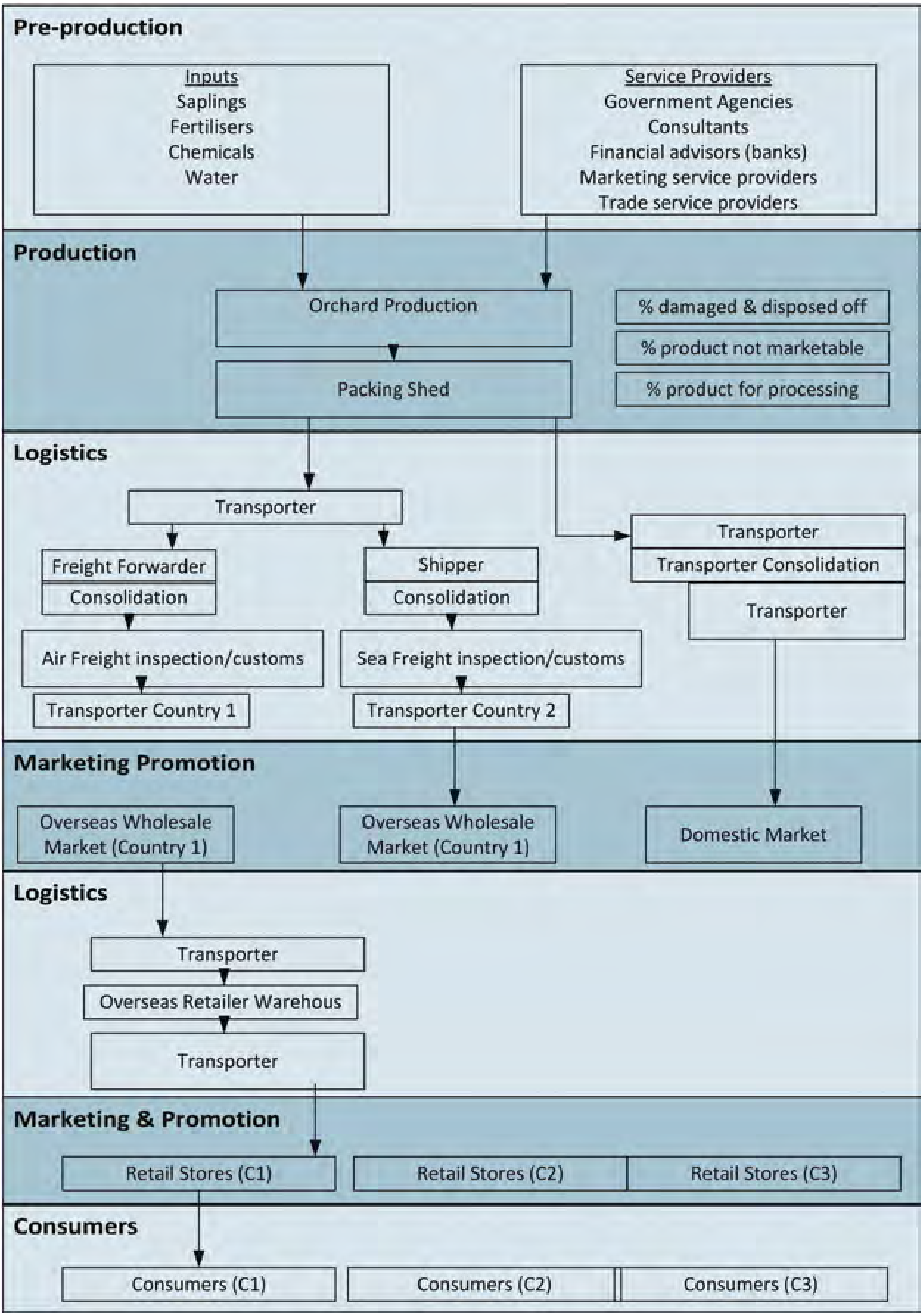


Figure 52. *Diagrammatic representation of a supply chain map of Australian apple exports.*

Pre-harvest process model of growing the crop

The following orchard process model (Figure 53) diagram indicates the many steps that occur during the growing of the apple crop. Some steps indicated do not follow a set order, but are implemented on a crop needs basis. Each input and process step represents a potential risk, where a food safety hazard may be introduced.

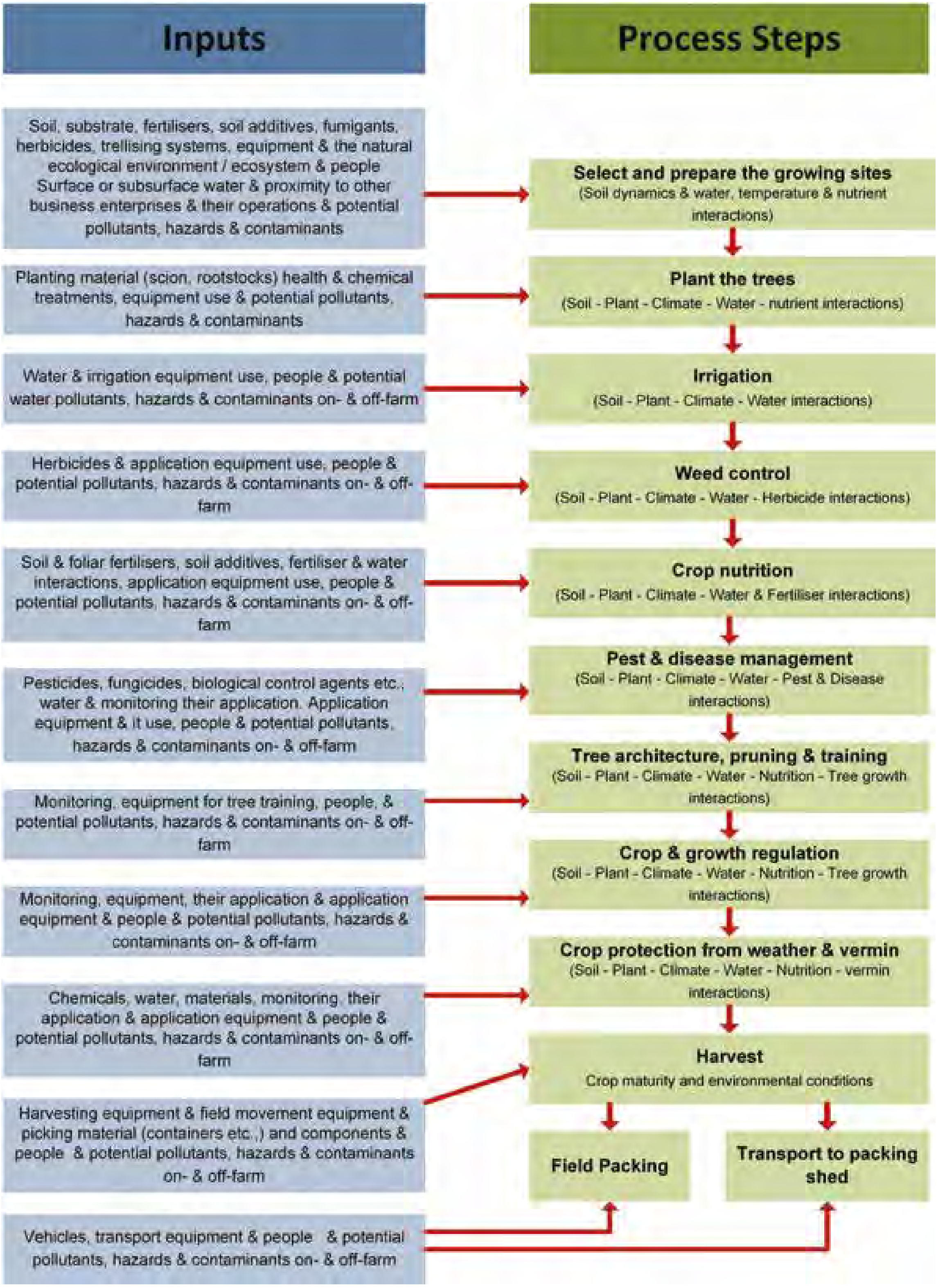


Figure 53. *Diagrammatic representation of inputs and potential safety risk areas in an apple orchard.*

Packing shed process model

The following diagrams indicate the many steps that occur during sorting, grading and packaging of the produce in the packing shed. Some steps indicated do not follow a set order. Each input and change in the process, represents a potential risk where a food safety hazard may be introduced. Figure 54 indicates the inputs and risk areas where food safety hazards may be introduced from receival of the produce at the packing shed through to placement of fruit into storage. Figure 55 indicates the inputs (risk areas) where food safety hazards may be introduced in the packing shed, once fruit is removed from storage through to packaging and dispatch to the target market.

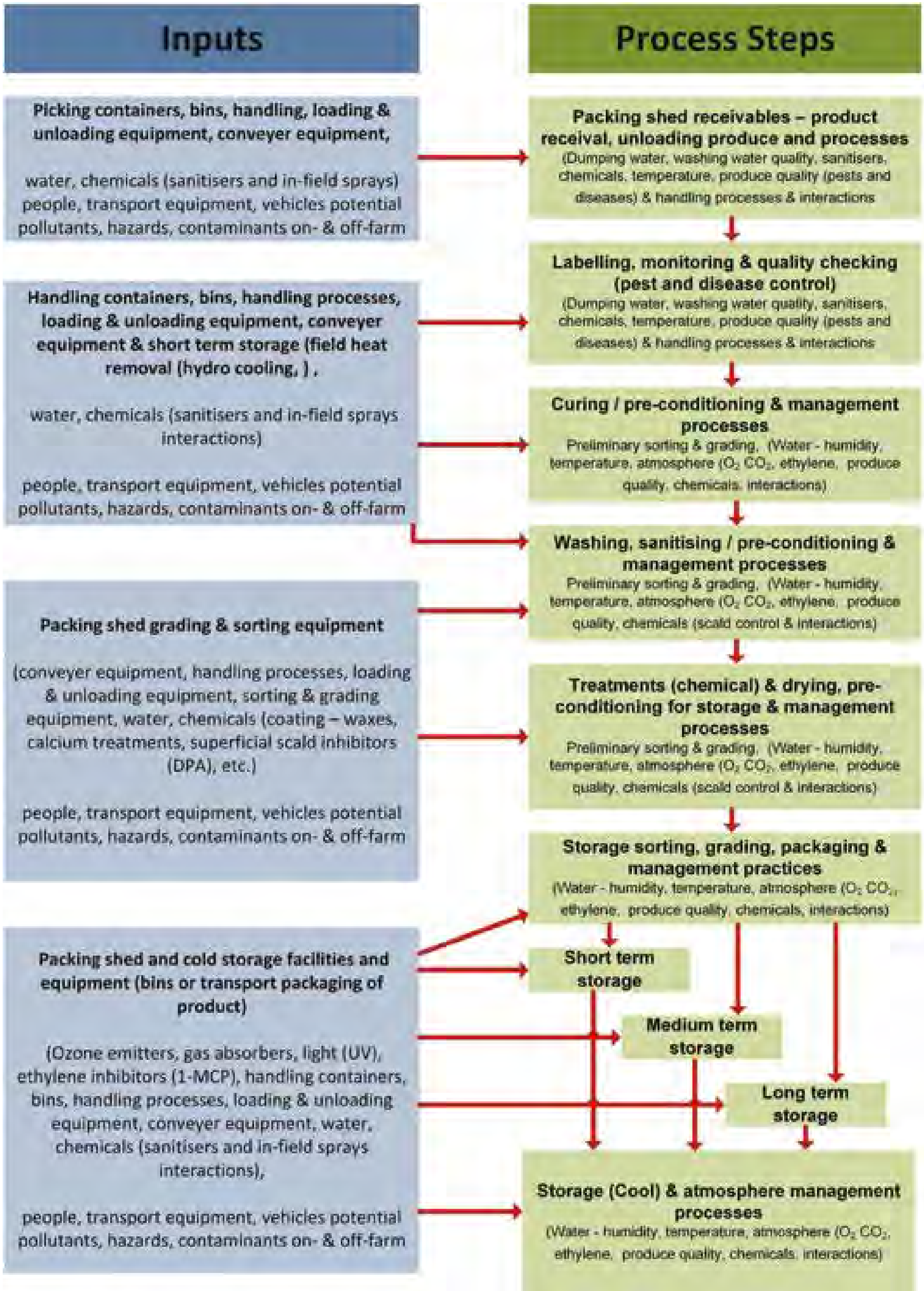


Figure 54. *Diagrammatic representation of inputs and potential safety risk areas in the packing shed from receival of fruit to placement into cool or atmospheric storage facility.*

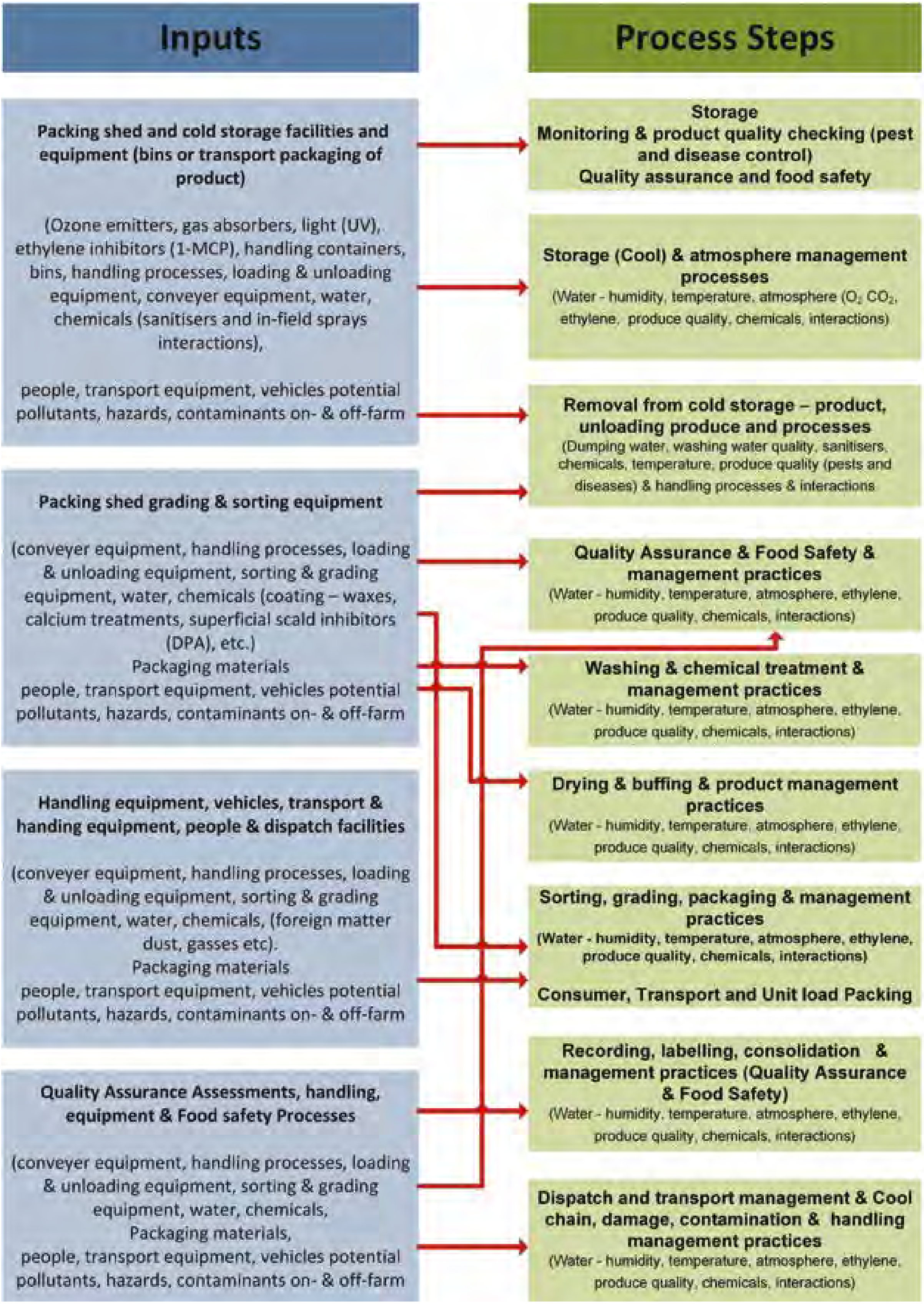


Figure 55. *Diagrammatic representation of inputs and potential safety risk areas in the packing shed from removal of apple fruit from storage through packing and dispatch to target market.*

Section 8: Analysis techniques to assist postharvest management

Understand your on-farm and packing shed processes to improve efficiency and effectiveness in maintaining fruit quality to obtain the highest return on your investment into the crop and your enterprise. Fully understand your processes to diagnose the real problems (blockage points) instead of the symptoms that frequently result in negative effects and unintended results. Undertaking an analysis of your on-farm and packing shed process enables you to optimise your activities that deliver to your consumers a product of optimal quality at the least cost.

Gathering all the information about the on farm processes and understanding the value chain that connects you to your consumers is crucial to achieving maximum efficiency and effectiveness, and thus ensure that your enterprise is sustainable and economical. When problems are encountered during the harvest, treating, sorting, grading, storing and packaging and marketing of your fruit, rather than just checking or fire-fighting and trying to develop a solution it is best practice to fix or improve your on-farm and packing shed processes by having a good design layout of the processes you undertake.

There are a multitude of analysis techniques that can be used to determine problems that need to be addressed. However you need to focus on the right things. While there are complex systems used in manufacturing industries to increase efficiency and decrease waste such as Six Sigma and lean manufacturing and Just In Time (JIT) inventory strategy, here we will focus on the basic problems to improve on-farm and packing shed efficiency and fruit quality and a few simple analysis techniques and examples. Harvesting and packing times, treatment, handling methods, and resource use have a substantial effect on fruit quality, its storability and ultimately customer and consumer acceptance.

There are many techniques you can use to conduct your analysis. Some of the analysis techniques that may be useful for apple enterprises are:

- Gap Analysis
- Cause and Effect Analysis
- Value-Added Analysis
- Root Cause Analysis
- Chronological Analysis
- Observational Analysis
- Critical Path Analysis
- Customer Requirements Analysis
- Process Constraint Analysis
- Value Chain Mapping

Below is an example of Gap Analysis, Value Added Analysis and Root Cause Analysis processes that you can use to assess your on-farm and packing shed activities and processes. Analysis of the process will provide you with the tools to produce a consistent, high quality product that will achieve greater customer and consumer acceptability. Not all the above techniques will be explained. The above list of analysis techniques is provided to assist growers and/or managers with their decision making.

Gap analysis process

Gap analysis is a very useful tool to identify those aspects and components that make up a process. Gap Analysis enables you to document, analyse and determine inefficiencies and problems within your process or value chain. It will provide you with the hard data to change your process practices to move from your current practice to an improved practice that is effective, efficient, sustainable and economically viable.

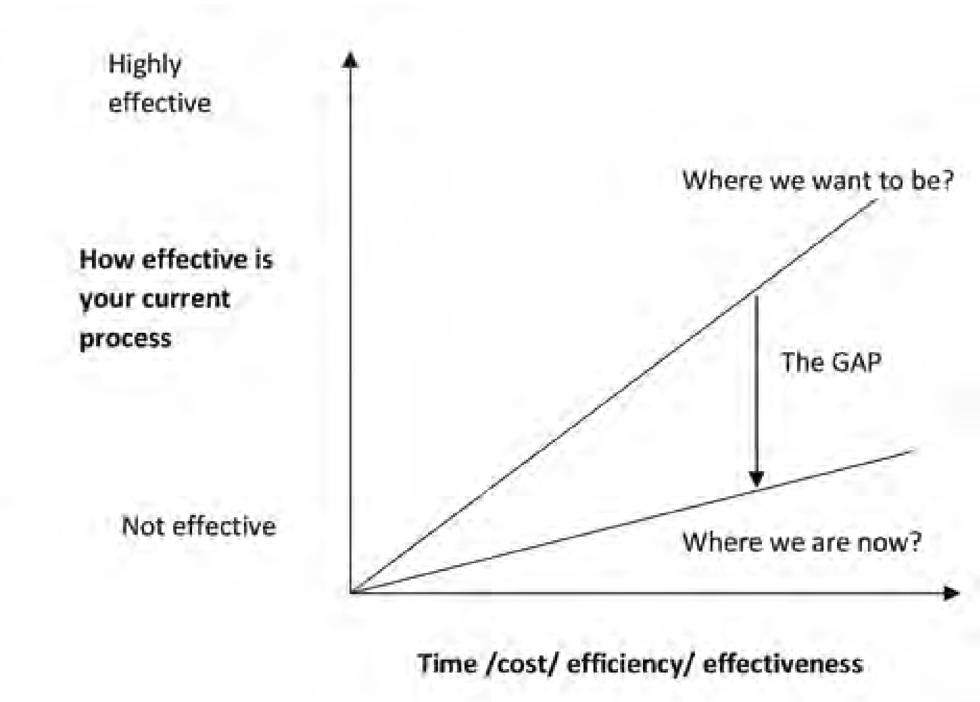


Figure 56. *Gap analysis diagram. The bottom line is where you are likely to be if you do nothing. The top line is where you want to be.*

Gap Analysis defines each component or process that is undertaken. For example Gap Analysis includes:

- Input: the task/activity/process component that is carried out on the product which may transform the product.
- Benchmark Guides: the component that determines why, how, when the task/activity/process is carried out on the product.
- Output: the component that is the result of the task/activity/process is carried out on the product.
- Enabler: a resource (person, facility, system, tools, equipment, asset etc.) that is used to perform the task/activity/process carried out on the product.

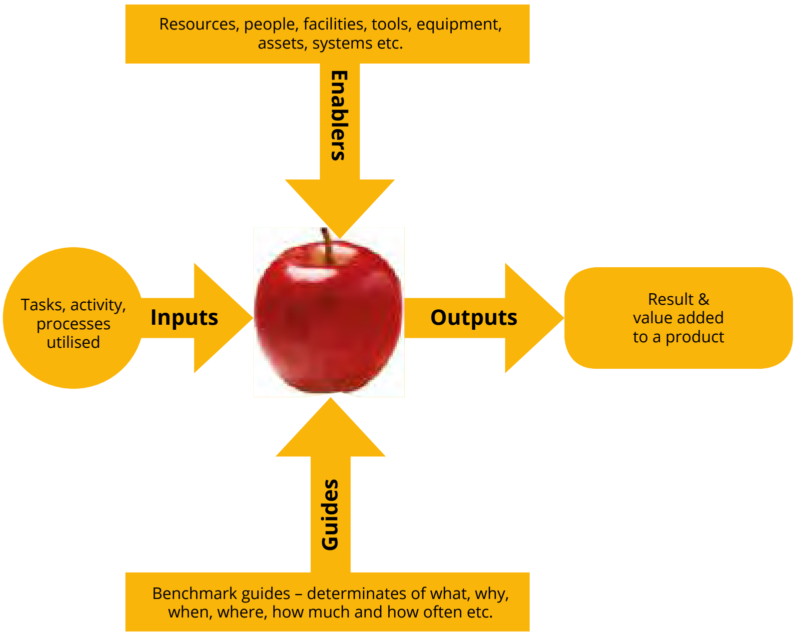


Figure 57. *Diagrammatic representation of a Gap Analysis framework.*

When undertaking a Gap Analysis and the task/activity/process, it is suggested you look at the process from the input and output perspective and consider some of the following components of the framework. Tables 10 and 11 show some suggested areas and thoughts that can be used as a guide.

Table 10. *Gap Analysis Framework.*

Input	Output	Enablers	Guides
Sequence of the events or process undertaken to add value to the product. Are the activities arranged in a logical flow or order of processes undertaken to add value to the product? Are there any redundant activities in different areas in the packing shed or in-field operations? Timing of activities: are the activities carried out in a timely and accurate manner?	Feedback loops about the processes and activities undertaken. Inappropriate format or packaging, grading, sorting, for customers or consumers? Unnecessary reporting or data collection.	Technology – the use of scientific knowledge. This is characterised into three levels: 1) over use; 2) appropriate level of use; 3) under use. This is the use of computerisation, creating information databases and using new technologies, e.g. equipment to facilitate a process and contribute to a positive cost benefit and value adding to the product. Facilities, grading (e.g. weight graders, sorting (e.g. colour sorters) and packaging equipment, cold rooms, packing sheds, transporting equipment, quality.	Policies and guidelines (e.g. product specifications and customer requirements). Training: Adequate training, education, knowledge and experience of staff to conduct activities to the level required. Inappropriate and unwanted data collection. Relevance and appropriateness of data and information. Inappropriate controls to monitor and product quality measurements. Processes that do not add value and provide a positive cost benefit, and ability to add value to customer and consumers of the product and the legitimacy of the measurements to improve the efficiency and effectiveness of the business enterprise.

Table 11. *Gap Analysis Worksheet – Apple Harvesting and Packing on Postharvest Process (Suggestions and thoughts).*

Process	What happens?	What can go wrong?	Who is responsible?	Comments
Harvesting	• How is this done (clip, break, pull, ladders, harvest aides)? • What is it picked into (plastic crates/ buckets, canvas picking bags, etc.)? • How long do they stay in the field? Where are they placed before pickup? • Maturity Stage and how is maturity assessed? • Conditions and temperature at harvest?	Immature fruit, physical damage, insect or disease damage, sun burn, too long in heat.	Grower, contractor, Work Group Supervisor, Quality Officer	Work safe procedures and training. Induction courses. Workplace Health and Safety Compliance. Each State has Induction courses. Workplace Health and Safety Organisation.
Carrying and unloading apples into picking bin	• What practices are used to carry the apples? • How full should bags/bins be? • Reactions by apple pickers to previous chemical sprays? Or Are any treatment solutions used on fruit that pickers may react with? • Picking height, ladders, harvesting platforms and picker safety? • Movement and management of fruit bins?	Pickers falling from ladders and platforms. Pickers riding on equipment in an unsafe manner.	Grower, contractor, Work Group Supervisor, Quality Officer	Work safe procedures and training. Induction courses.
Transport to packing facility	• Apples are tipped out of field containers into a larger bin? • What sort of vehicle is used? • Is it covered or open? • How are containers stacked and strapped on vehicle? • How long does it take to get to where it will be packed? • What are roads like?			
Packing	• Where is packing done? • What facilities are there? • Is washing done? • Is polishing done? • Is waxing done? • Is it a shed or covered area? • Are there any time delays before packing? • Is fruit sorted and graded for appearance or size? • Are there any grade standards/ specifications? • Is there any postharvest disease treatment? What? Hot or cold? • Is there any postharvest insecticides used?			

Process	What happens?	What can go wrong?	Who is responsible?	Comments
Packing (cont.)	• What packaging is used (fibreboard – where manufactured, wood, baskets)? • Are there any protection aides (liners, newspaper, socks)? • Are they single layer or multi layer? • Place packed or volume filled? • Is there a quality inspection on arrival? • Is a packed product inspection done? • Are cartons palletised? How is it strapped? • Is any pre-cooling done? What temperature and conditions? For how long? • Is any long term storage CA (low O_2, CO_2) rooms and how is this achieved? • Is there any product ID on packaging/ • Is there any communication with the next customer (info on what's coming, size, grade)?			
Transport	• Who is doing the transport? • What type of vehicle? • Covered? • Refrigerated, CA? • What temperature? • Destination? • How long? • Any documentation?			
Wholesaler/ trader	• Is an assessment done on arrival? • Any repacking? • Held in what conditions for how long, what temperature? • Cool room? • Is ripening handled? How? (ethylene (C2H4). How long? • Is a despatch check done? • Any documentation?			
Transport	• Who is doing the transport? • What type of vehicle? • Covered? • Refrigerated? • What temperature? • Destination? • How long? • Any documentation?			

Process	What happens?	What can go wrong?	Who is responsible?	Comments
Supermarket DC	• Is an assessment done on arrival? • Any repacking? • Held in what conditions for how long, what temperature? • Cool room? • Is ripening handled? How? (ethylene (C_2H_4). How long? • Is a despatch check done? • Any documentation?			
Retail shop	• Where is product held? (back of shop, cool room) • What conditions? • How long? • How are they displayed?			
Export warehouse/ freight forwarder	• Is an assessment done on arrival? • Any repacking? • Held in what conditions for how long, what temperature? • Cool room? • Is ripening done? How? (ethylene (C_2H_4). How long? • Is a despatch check done? • Any documentation?			
Export transport	• Who is doing the transport? • What type of vehicle? • Covered? • Refrigerated? • What temperature? • Destination? • How long? • Any documentation?			

Value added analysis

The value added analysis examines in detail every activity/task and process undertaken to bring a product to your customer and ultimately the end consumer. Value added analysis is used in conjunction with process analysis, root cause analysis and time analysis. Each activity/task/process, once completed, must create an outcome or output that creates value for your customer and the end consumer. Therefore, optimisation of the activity/task/process is carried out to eliminate any waste or non-value enhancing steps. Each activity/task/process and the steps carried out can be placed into three categories:

1) Real Value-Added;

2) Essential Enterprise Value-Added;

3) Waste (No or Non Value-Added).

See Figure 58 for a decision making process to identify if the activity/task/process adds value.

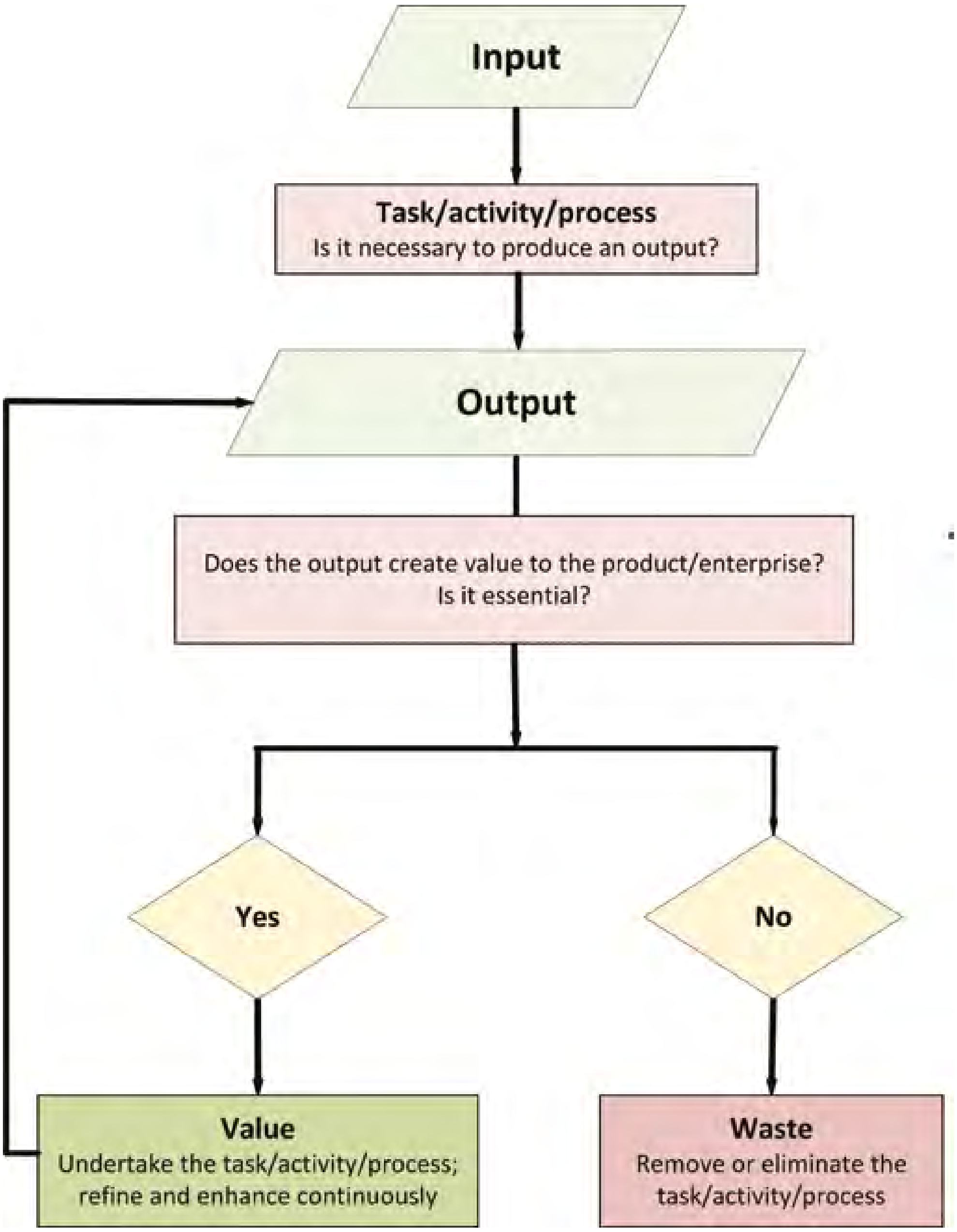


Figure 58. *Value-Added Analysis flow chart for decision making.*

Why do a value-added analysis? Approximately 80% of all processes have elements of non-value work. You may wish to ask yourself these questions about your on-farm processes:

- The product, its physical changes and the inputs to enhance the product undertaken on-farm, is your customer and end consumer willing to pay?
- Do the activities/tasks and processes undertaken provide your enterprise with a benefit?
- Is it a real value-added or Essential Enterprise Value Added benefit?

During your Value-Added Analysis you may wish to undertake the following steps as indicated in Table 12 below. These are only a suggestions and you may wish to develop your own.

Table 12. *Suggested steps for value-added analysis.*

Steps	Some suggested content ideas
1. Define and Clarify	• Define the activity/task and process boundaries. • Determine the customer, consumer and time line requirements • Identify the requirements of the activity/task and process. ○ Define the defect and the defect measures that are associated with the activity/task and process. ○ Determine the estimated financial benefit of the activity/task and process.
2. Gather the required information	• Understand the activity/task and process. • Develop a process map. • Collect reports created during the activity/task and process. ○ These reports may be in the form of numerical data, graphs, etc. ○ Collect feedback reports from customers and final consumers
3. Compile and summarise your findings	• Create a flow diagram (cause and effect, fishbone or root cause diagram). • Establish process capability • Calculate unit inputs and the categories for the different unit outputs and waste etc.
Analyse the information	
Determine what is required	
Plan the actions to be undertaken for improvement and implement	
Monitor and evaluate the performance of the enhanced or improved process	

The Value-Added formula is: VA= SP-CP

VA = value added

SP = sale price of the product

CP = cost of producing the product

In the cost of producing the product you must include:

- annual ownership costs of the equipment (fixed costs)
- operating costs of the equipment (variable costs)

Ownership costs or fixed costs includes all the estimated costs such as:

- depreciation
- interest (opportunity costs)
- taxes
- insurance
- housing and maintenance costs

Operating costs or variable costs include:

- repairs and maintenance
- fuel/electrical
- lubrication
- operator labour

Cause and effect / root cause analysis

These analysis methods are used to study and determine the task/activity/process in order to define where an issue may exist or where a potential blockage, bottleneck or problem may occur.

Cause and effect analysis / root cause analysis is part of quality management and is a quality control tool. The diagrams are called "cause and effect diagram" or "root cause diagram" or "fishbone diagram" or "Ishikawa diagram" after the inventor. This analysis can discover the cause of the issue, blockage, bottleneck, or problem.

A similar analysis process is the CATWOE analysis method. In this method the issue is viewed from six different perspectives. Below is a table with some examples of how to use CATWOE analysis. The categories used are:

1. Customers and consumers (revenue is generated from your customers and ultimately the consumer)
2. Actors - employees (people involved in the task/activity/process), suppliers, agency officials etc.
3. Transformation process - individual elements of the procedure undertaken
4. World View - look at the bigger picture and determine long-lasting or far reaching effects. There may be an oversupply of produce in one market that is being shipped and supplied to your target market at a lower price. In addition Free Trade and Bi-Lateral Agreements between countries, CODEX Regulations and requirements, Tariffs, Taxes, Facilitation Fees and Trade Embargoes etc.
5. Owner (Business Enterprise) View - usually involves financial gross margin analysis, and management perspectives of the company
6. Environment (environmental constraints include the physical environment (climatic conditions, soil type etc.) the location and proximity to markets, available resources, financial resources, laws and regulations domestically).

Table 13. *The CATWOE analysis*

Category	Some suggested content ideas
Customers and Consumers	Fruit arriving in a condition that is acceptable but shelf life is short. Consumers indicate that some fruit break down quickly before their purchase is consumed. (Cause Category 2).
Actors	Employees not handling the fruit carefully enough. Fruit sit in the sun before being collected and taken to the packing shed. (Cause Category 1). Majority of fruit packed are of good quality however a percentage of less than desirable fruit are also being packed. (Cause Category 1)
Transformation Process	Fruit with less than desirable temperature are being packed. Fruit temperature not maintained correctly. (Cause Category 1).
World View	Target market is in oversupply due to a competing country that has had a bumper year and higher than expected yields (Cause Category 3).
Owner (Business Enterprise)	Equipment used to pack produce is outdated and in need of upgrade, running costs are higher than usual and time lines on processes are expanding. (Cause Category 2).
Environment	Seasonal temperatures were above average and the crops matured quickly. Difficulty in keeping up the required irrigation requirements. Road transport companies are proving difficult to deal with. Availability and timing of transport vehicles to and from enterprise location (Cause Category 1).

For the cause and effect analysis you must work out the major factors and their interactions within the task/activity/process or procedure performed. Draw out a fishbone diagram listing all elements that are involved in the task/activity/process.

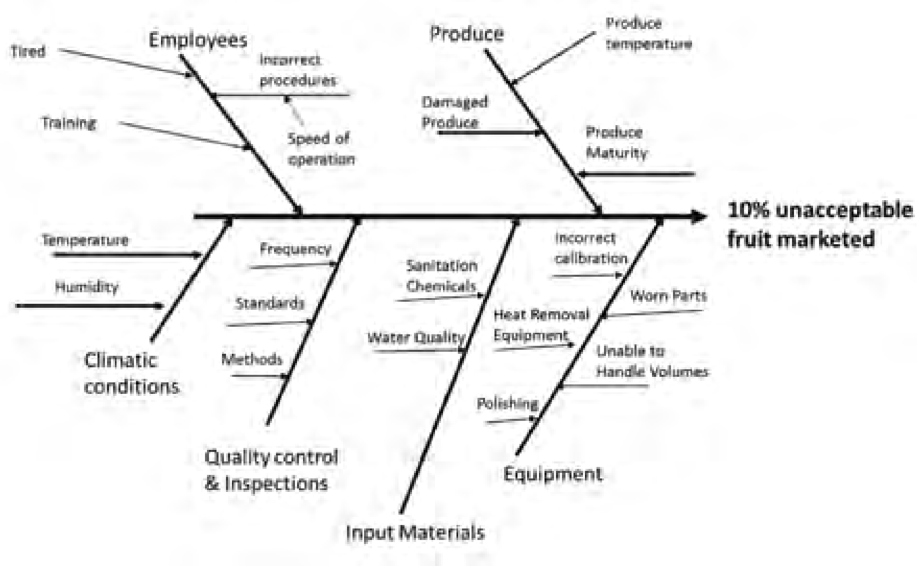


Figure 59. *Cause and effect diagram.*

When determining the root cause of an issue, the approach and tools you use should determine all the factors involved in the task/activity/process being investigated. The true cause ("root", "basic", "fundamental", "initial" or "underlying" cause) of the issue has to be identified, not the result or symptom. Root cause analysis can result in several levels that cause the issue or problem and identifying this is critical in identifying the root cause of the issue.

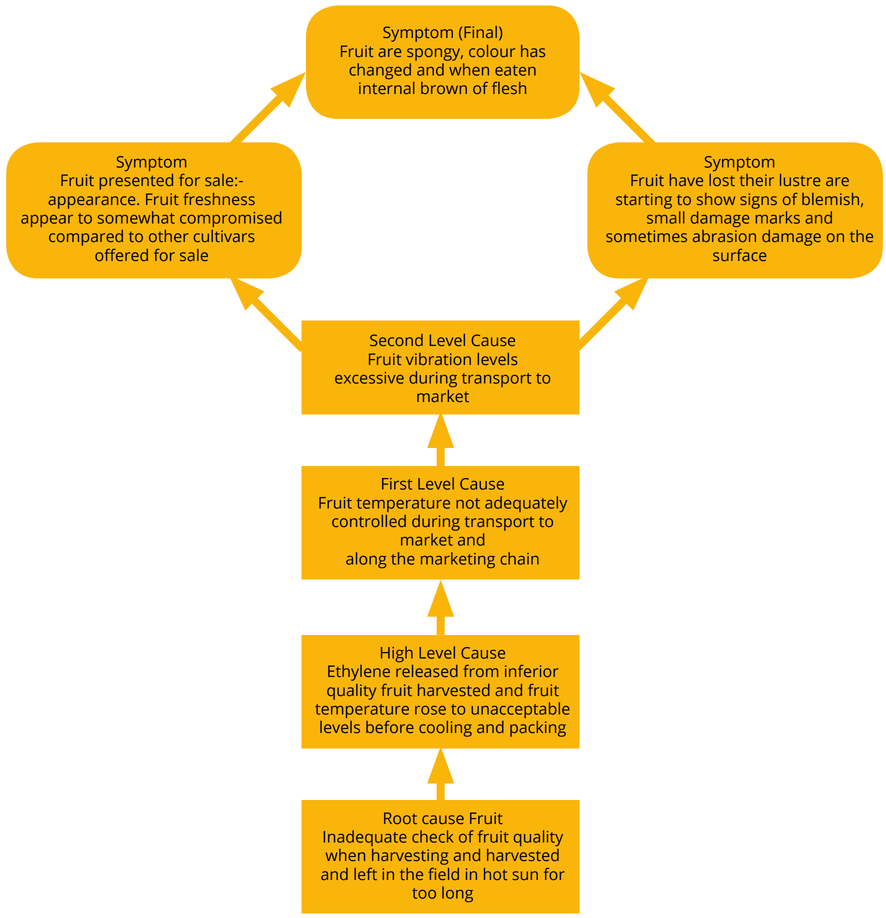


Figure 60. *Root cause diagram.*

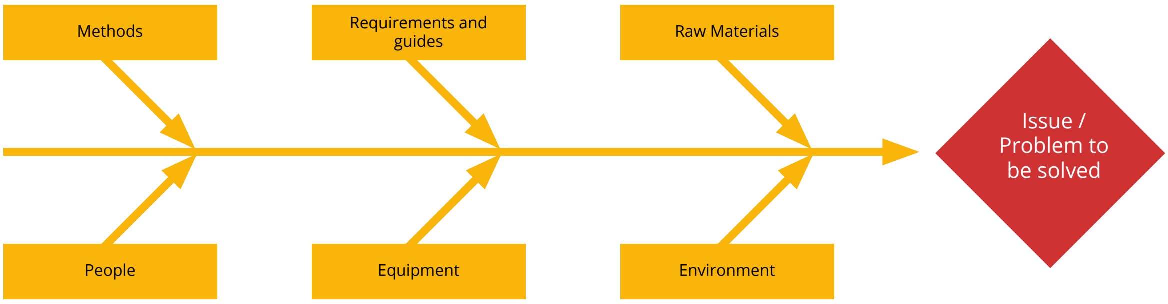


Figure 61. *Related activity process areas that contribute to a root cause.*

Packing shed operations

Higher apple prices can be achieved by improving the quality of apple pack-outs through investment in reducing handling costs, and packaging, storing and marketing apples when market prices, volumes and consumer demands provide optimal returns. Apples are best sorted and graded into different grades and sizes that command higher prices compared to mixed lines of apples.

A packing shed system incorporates a range of resources in one place (labour/personnel, raw materials, and utilities, produce protection from the elements, technologies, equipment, shelter, storage, delivery and dispatch point of contact) on a farm or within a region to improve efficiency and economic returns for the farming enterprise.

The standard of the packaging facility is related to the consumer and market requirements. A packing shed has several basic functions or key operations:

- removal of unmarketable product
- sorting (by maturity, size and defects)
- grading
- packaging
- consolidation of the product
- storage and dispatch point of contact

In-field preparation and packing shed operations are not mutually exclusive. It is a waste of time and money to handle and pack unmarketable fruit. Therefore, in-field operations is where the initial sorting and grading occurs to remove product with severe defects, pest and diseases and damage. The efficient culling of rejects from good quality produce is best achieved in the packing shed where a combination of manual and automated systems can be implemented.

A packing shed allows for operations to be performed any time of the day or night. Because of the potential to handle large volumes of produce, packing sheds can be used by farmer associations, cooperatives or even community organisations. There are an enormous variety of packing shed designs and facilities, but essentially a packing shed protects the product and personnel from the weather and provides a centralised area for product preparation, sorting, grading, handling, packing and storing operations.

Benefits of using a packing shed

- Increased productivity of workers - a well-equipped and designed packing shed will enable workers to perform their tasks with higher efficiency. This will decrease errors in sorting and grading and increase volumes of produce handled.
- Extended product shelf life – preparation of the produce for market by well trained workers ensure the best postharvest handling processes are in place. This minimises mechanical damage of the produce, decreases potential disease development and minimises the ripening rate and product deterioration.
- Improved produce quality – produce unsuitable for marketing (rejects) are culled efficiently and prevention of disease cross contamination and premature deterioration results in improved produce quality delivered to your customer, the target market and ultimately the consumer.

Special operations are performed in the packing shed and these can run continuously for 24 hours regardless of the weather conditions outside. The degree of complexity, size of operation, tasks performed (automated and hand labour) and processes undertaken depend upon the following factors: volume of the crop, objectives of the farming enterprise, the target market requirements (quarantine, quality assurance and food safety standards) and consumer preferences.

Packing shed design

Packing sheds need to be located close to the production area and within easy access to main waterways and roadways/highways. It should facilitate the delivery and supply of produce with enough space to avoid vehicle congestion when entering and leaving the facility.

The packing shed should protect the produce from unfavourable conditions and stop rapid deterioration in produce quality. It should have adequate room for easy circulation of equipment and vehicles to move produce, and doors and spaces large enough to allow for equipment to move easily in and out of the shed and around the shed.

Lighting should be between 2000 and 2500 lux and working areas should have no contrasts caused by shading, or workers exposed to temporary blindness when eyes are raised for normal movement or communication with other personnel. Dull colours and non-glossy surfaces are required for equipment, conveyer belts and outfits as high colours can cause eye fatigue and stop workers selecting fruit with defects due to reflection.

A good potable water supply is critical for washing produce, bins and equipment, as well as for workers to wash their hands to mitigate against contamination. A good waste water disposal system is needed to ensure the environment is protected on and off your farm.

Administrative offices and quality assurance assessment laboratories should be located in clean quiet areas.

Building layout should facilitate the movement of produce through the packing shed. Handling of produce must be minimised and movement of produce should always be in one direction with no crossovers. The building should allow concurrent operations to be undertaken. A well designed and ergonomically efficient packing shed will reduce labour costs associated with packing. Apple packing sheds use a variety of standard procedures and processes, however, there can be large variation between packing sheds in the processes and equipment used. A standard sequence of packing shed processes and model is presented in Figures 51, 52, 54, 55, but changes to this sequence are dependent upon each enterprise operation and setup.

Packing shed fruit receiving area

The packing shed receiving area should be sealed and if possible covered to avoid produce from being exposed to the elements (e.g. direct sunlight, rain, dust etc.) The area surrounding the packing shed should be well grassed to avoid dust being blown inside the shed and onto produce.

Delays frequently occur in the reception area because produce is normally counted before entering the packing shed and sometimes quality samples are taken for quality analysis.

Appendix 1: Fruit defects, disorders & diseases

1. Pre-harvest physical & physiological defects/disorders and diseases

Russet

Russet develops on fruit that suffers damage to the cuticle early in the growing season. A layer of cork cambium develops and pushes outwards to replace the cuticle. The amount of russet depends on the degree of injury. Fruit is most sensitive to damage from pink bud through to 6-8 weeks after full bloom, but exposure to russet inducing events later in the season can cause further damage. Russet does not affect taste or other quality parameters but reduces the visual appeal of the fruit and hence has a serious detrimental effect on market value.

Limb rub

Limb rub marks are produced by fruit rubbing against limbs or sometimes leaves of the tree as the fruit matures. They are generally recognized by a scar which is smooth to hard, sometimes bark-like and the colour varies from light brown to black. There is normally a corky or hard mass of tissue beneath the skin marks.

Frost

Frost occurring during blossom or fruit set can cause complete fruit loss.
Damage to fruit can range from a characteristic frost ring to lesser scarring/russeting that can sometimes appear similar to russet induced by powdery mildew; however mildew russet is more netlike across the fruit.

Hail

Hail damage can occur at any time during the season. Damage varies depending on fruit growth stage, size/shape of hailstones and duration of the event. Injury can range from torn/shredded leaves and small dents in the fruit to loss of the entire crop due to physical damage and bruising. Bark injury can also result, particularly on young trees and younger wood, and stems and branches can be broken. Damage to the bark and/or fruit cuticle provides an entry point for fungal diseases, so fungicide application may be necessary.

Sunburn

Yellow or flushed areas on the fruit skin due to direct sun damage often following a period of cooler, cloudy weather. In severe instances, the scald damage turns dark while the fruit is still on the tree, with the underlying tissue becoming spongy. Also associated with lack of calcium in the fruit.

Water core

Water core is characterised by water-soaked regions in the flesh of the apple. It develops in mature fruit when the sugar sorbitol, is translocated into the fruit faster than it can be assimilated. The area surrounding the core becomes water-soaked or translucent and may appear glassy and hard.

In mild and moderate cases, it is more commonly found near the core and around the primary vascular bundles but it may occur in any part of the apple. In severe instances symptoms may be seen on the outside of the fruit.

Bruising

Bruises are seen as depressed or flat areas of the surface that yield readily to slight pressure, and are usually accompanied by discoloured, soft and/or disintegrated flesh, usually brown in colour, but not decayed. They are a result of impact and/or compression of the fruit, and can occur either pre-harvest, or during harvest, post-harvest handling, transporting, packing and distribution. The severity of impact damage is related to height of fall, initial velocity, number of impacts and type of impact surface. Small fresh, watery or translucent bruises which are not discoloured will normally heal in a short period of time in storage.

Bitter pit

Bitter pit is a physiological disorder associated with Ca deficiency – cell walls of affected fruit collapse and pit cavities are formed

Symptoms are more often seen in storage as deep brown or black lesions or spots varying from 2-10mm in diameter. Shallow brown areas beneath the spots resemble small bruises. Early symptoms are seen near the fruit's calyx as small, water-soaked spots on the skin.

Lenticel blotch

More prominent than bitter pit, these slightly sunken irregular shaped blotches result in underlying tissue drying out and becoming brown and spongy. Blotches are usually near the calyx end of the fruit.

Occurrence is associated with hot summers, late harvests and excessive use of nitrogen. Pitting is always associated with a lenticel.

Insect damage

Insects can cause a range of damage, including deep entries, stings or surface feeding Early surface feeding causes distortion of the fruit; mid to late surface feeding causes either shallow holes or surface tunnelling

Deep entries are a problem in stored fruit as they often result in bacterial or fungal entry that leads to fruit rot.

Malformed Fruit

Strongly misshapen or cracked fruit with associated spongy tissue underneath the skin. Often linked to boron and occasionally zinc deficiency, but may also be due to insect damage.

Pygmy fruit

Small seedless fruit that stop growing early in the season but persist on the tree until harvest. Can be caused by growth regulators and/or interactions between chemicals.

Apple scab / black spot *(Venturia inaequalis)*

A fungal disease, scab appears as irregular circular spots usually 3 to 19mm diameter, with a dark green to nearly black velvety surface in the early stage, developing into a brown, russeted, rough surface with a fringe of light to dark green or even black around the margin. The spots are usually most numerous around the blossom end, and when infection is severe they may coalesce and form large irregular lesions 25mm or more across.

Powdery mildew *(Podosphaera leucotricha)*

Caused by a fungal pathogen, it is the second most serious disease after black spot. High humidity (>70%) and temperatures above 20°C provide ideal conditions; unlike other fungal pathogens, it does not require rain to develop.

Damage to leaves and shoots slows and distorts growth. Because much of the damage is not directly to the fruit it is difficult to quantify losses, but heavy infections over several seasons can reduce yields by up to 80%.

Infected floral buds will abort, or produce small stunted or russeted fruit. The russet has a characteristic netlike appearance.

Alternaria leaf blotch and fruit spot *(Alternaria sp.)*

Leaves: Lesions first appear as small, roundish purplish or blackish spots that gradually enlarge. Heavy summer rainfall triggers disease development, and the number and size of lesions explodes. They become light brown with a distinctive purplish border irregular shape, coalescing to form large necrotic areas. Leaves turn yellow and drop.

Fruit: Small, slightly sunken, light to medium brown spots appear on the lenticels of the fruit, often soon after rainfall, and usually no earlier than 6 to 8 weeks before harvest. Spots do not enlarge during cold storage but once fruit is removed from cold storage existing spots continue to grow in size, and new spots can develop, providing an excellent entry point for other secondary fruit rots.

Image source: http://apal.org.au/wp-content/uploads/2013/11/AP02011-Management-of-Alternaria-leaf-and-fruit-spot-in-apples.pdf

Bitter rot *(Glomerella cingulate)*

(also known as *Colletotricum spp.*)

A fungal disease. Most serious fruit rot in warmer, more humid regions, but can become a problem in any region given favourable conditions.

Damage varies depending on whether infection is caused by sexual or asexual spores. Asexual spore infection is more common with development of circular lesions that become larger and sunken as the disease progresses. Ooze containing salmon to pink coloured spores develop in concentric circles on the surface of the lesion around the point of infection.

2. Storage disorders

One of the most important steps in reducing risk of post-harvest physiological disorders is picking at correct harvest maturity as the risk of many disorders is increased when fruit is picked outside of optimum harvest maturities. Superficial scald, bitter pit and shrivel are more likely to occur in early-picked fruit, while yellowing, internal browning and some types of water-core are more likely in late-picked fruit.

Superficial scald

Results in irregular brown areas of dead skin and arises when apples are transferred to warm air from cold storage. Believed to be associated with the toxic accumulation of volatile substances released as a result of metabolism during storage.

Storage scald is worse in poorly ventilated stores, during hot summers, and is associated with high levels of nitrogen and lack of calcium in the fruit.

Image source: http://www.yara.us/agriculture/crops/apple/key-facts/market-requirements/

Internal browning

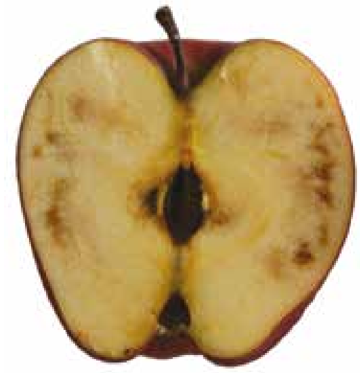
Internal browning is a low-temperature storage disorder of certain apple cultivars that develops in fruit stored at 1-2°C. Affected tissues are brown and firm; the browning may be confined only to the core or the core area can be normal and browning is in the outer layers. Firm fruit allows the diagnosis of internal browning from other internal physiological disorders. High CO_2 levels seem to induce flesh browning symptoms in Delicious and Pink Lady apples.

Seasonal and orchard factors are thought to influence the susceptibility of fruit to the disorder in CA storage.

Internal breakdown

The breakdown of internal tissues resulting from fluid oxidation. Characterized by flesh browning and breakdown; in severe cases, tissues become spongy. Internal symptoms may be restricted to one side of the fruit, or involve the entire fruit. Often there is a ring of healthy flesh surrounding the affected tissue.

Over-mature and large fruit are highly susceptible. Can be associated with intense water core, boron and phosphorus deficiency, and cold storage.

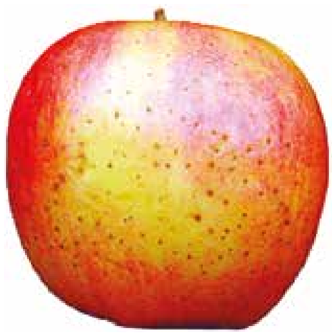


Lenticel breakdown

A skin disorder that appears largely after the fruit has been packed. Gala is most susceptible to lenticel breakdown, but the disorder has also been seen to a much lesser extent on Delicious and Fuji, especially after long-term storage. When cooling is delayed after harvest, the risk of lenticel breakdown increases.

Mild cases resemble chemical burn, which causes the lenticels to turn black. In more serious cases, the flesh under the lenticel sinks, creating a crater. Not to be confused with lenticel blotch pit.

Image source: Good Fruit Grower, Sep 7, 2000



3. Storage pathogens

Blue mould *(Penicillium)*

Blue mould originates primarily from infection of wounds such as punctures, bruises and limb rubs on the fruit.

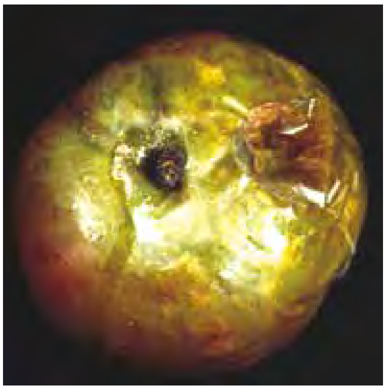
The decayed area appears light tan to dark brown and tissue is soft and watery. The lesion has a sharp margin between diseased and healthy tissues. Decayed tissue can be readily separated from the healthy tissue, leaving it like a "bowl". Blue or blue-green spore masses may appear on the decayed area, starting at the infection site. Decayed fruit has an earthy, musty odour. The presence of blue-green spore masses at the decayed area and associated musty odour are the positive diagnostic indication of blue mould.

Mucor rot *(Mucor piriformis)*

A wound rot, invading fruit through damage. In most seasons causes losses at low levels in stored fruit. Symptoms are a pale to mid-brown, very soft wet rot. Rapid softening of the tissues occurs leading to a slimy disintegration of the flesh, the skin collapses under the slightest pressure. A profuse growth of white coarse mycelium bearing black pin-shaped spore heads may be present.

Fruit becomes infected through contamination with soil during wet harvests, or from contaminated drench tank water. Bare earth orchards are likely to have a greater risk of Mucor rot.

Image source: http://apples.ahdb.org.uk/mucor-rot.asp



Anthracnose *(Neofabra sp.)*

The most typical symptom is the appearance of cankers on twigs and branches. Young leaves or fruits can also be affected and develop brown spots and patches, that in the case of fruits cause "bull's eye rot" during storage. In particularly susceptible cultivars, it can lead to defoliation of the tree and reduced vigour, leading to a reduction of fruit quality.

The fungus survives on infected plant debris or in the soil, thriving under moist and warm conditions, with frequent rainfalls. Spores are spread via irrigation water or rain splashes. They can enter trees through small injuries but can also penetrate uninjured bark.

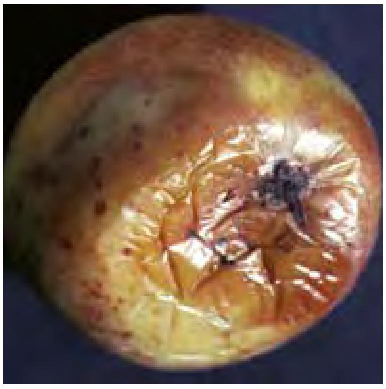
Image source: http://treefruit.wsu.edu/crop-protection/disease-management/apple-anthracnose

Grey mould *(Botrytis cinerea)*

Grey mould originates primarily from infection of wounds such as punctures and bruises that are created at harvest and during the postharvest handling process.

The brown decayed area is spongy, and diseased tissue is not separable from the healthy tissue, unlike blue mould. Under high relative humidity conditions, fluffy white to grey mycelium and greyish spore masses may appear on the decayed area. Grey mould does not have a distinct odour, but in advanced stages decayed apples may have a cedar-like smell. In advanced stages, the entire decayed fruit may appear "baked" and eventually may turn softer than in the early stage.

Image source: http://apples.ahdb.org.uk/botrytis-rot.asp



Appendix 2: Web links and references

1. Weblinks

Section 3: Optimising fruit quality in the orchard

Sun Protection for Fruit: a practical manual for preventing sunburn on fruit:
http://www.hin.com.au/__data/assets/pdf_file/0018/17730/Sun-Protection-Manual-for-Fruit.pdf

Section 4: Postharvest handling

Food and Agricultural Organisation (FAO) and World Health Organisation (WHO) International Food Standards CODEX Alimentarius Codex Standard for Apples –CODEX STAN 299-2010:
http://www.fao.org/fao-who-codexalimentarius/sh-proxy/en/?lnk=1&url=https%253A%252F%252Fworkspace.fao.org%252Fsites%252Fcodex%252FStandards%252FCODEX%2BSTAN%2B299-2010%252FCXS_299e.pdf

Consumer packages and the Codex General Standard for the Labelling of Pre-packaged Foods (CODEX STAN 1-1985): **http://www.fao.org/docrep/005/Y2770E/y2770e02.htm**

Codex General Standard for Contaminants and Toxins in Food and Feed (CODEX STAN 193-1995):
http://www.fao.org/input/download/standards/17/CXS_193e_2015.pdf

International Code of Practice – General Principles of Food Hygiene (CAC/RCP 1-1969):
http://www.fao.org/input/download/standards/23/CXP_001e.pdf

Code of Hygienic Practice for Fresh Fruits and Vegetables (CAC/RCP 53-2003):
http://www.fao.org/input/download/standards/10200/CXP_053e_2013.pdf

Principles for the Establishment and Application of Microbiological Criteria for Foods (CAC/GL 21-1997):
http://www.fao.org/input/download/standards/10741/CXG_063e.pdf

FAO website for updates and news on changes to the Codex Alimentarius Commission:
http://www.fao.org/news/story/en/item/1024512/icode/

Forced-Air Cooling Systems website: **http://www.omafra.gov.on.ca/english/engineer/facts/14-039.htm**

Washington State University Postharvest Information Network website:
http://postharvest.tfrec.wsu.edu/pages/N4I1A

Section 5: Packaging

Trade Item Implementation Guide (GDSN 3.1 Release 25.3 Ratified, Sept, 2017):
https://www.gs1.org/docs/gdsn/tiig/3_1/GDSN_Trade_Item_Implementation_Guide.pdf

IFPS PLU User's Guide and IFPS PLU Codes
http://www.ifpsglobal.com/Identification/PLU-Codes/PLU-codes-Search

EAN-13 vertical bar pattern and spaces encoding the GTIN 13 number generation:
http://www.gs1au.org/resources/check-digit-calculator

Rules relating to GTIN can be viewed at the GSI website:
http://www.gs1.org/1/gtinrules

GS1 Application Identifiers can be found at
www.gs1au.org

Traceability for Fresh Fruits and Vegetables Implementation Guide Issue 1:
https://www.producetraceability.org/documents/Global_Traceability_Implementation_Fresh_Fruit_Veg.pdf

GS1 Fruit & Vegetable GTIN Assignment Implementation Guide Release 2.0.1, Ratified, June 2016:
https://www.gs1.org/docs/freshfood/Fruit_and_Vegetable_GTIN%20Assignment_Guideline.pdf

GS1 Fresh Fruit & Vegetable Labelling Consumer Units Guideline, Release 1.0.1, Ratified, July 2015:
https://www.gs1.org/docs/freshfood/GS1_Fresh_Fruit_Vegetable_Labelling_Guideline.pdf

Section 6: Supply chain practices

HACCP principles and guidelines as outlined by the Codex Alimentarius, CAC/RCP 1-1969, rev. 4-2003:
http://www.fao.org/docrep/005/y1579e/y1579e03.htm

Freshcare™:
http://www.freshcare.com.au

Woolworths Quality Assurance Manual (WQA version 7):
http://www.wowlink.com.au

Coles Supplier Charter and Food Manufacturing Supplier Program:
http://www.supplierportal.coles.com.au/csp/wps/portal/web/Home

2. References

Boyette M and Estes E (1992) Proper Postharvest Cooling and Handling Methods, Postharvest Technology Series, North Carolina State Extension Service Publication 1st, October, 1992, Ag-414-04.

Watkins JB and Ledger S (1990) Forced-Air Cooling, Queensland Department of Primary Industries Second Edition, ISSN 0727-623.

Appendix 3: Codex Standards for Apple

STANDARD FOR APPLES

(CODEX STAN 299-2010)

1. DEFINITION OF PRODUCE

This Standard applies to fruits of commercial varieties (cultivars) of apples grown from Malus domestica Borkh, of the Rosaceae family, to be supplied fresh to the consumer, after preparation and packaging. Apples for industrial processing are excluded.

2. PROVISIONS CONCERNING QUALITY

2.1 MINIMUM REQUIREMENTS

In all classes, subject to the special provisions for each class and the tolerances allowed, the apples must be:

- whole, the stalk (stem) may be missing, provided the break is clean and the adjacent skin is not damaged;
- sound, produce affected by rotting or deterioration such as to make it unfit for consumption is excluded;
- firm[1];
- clean, practically free of any visible foreign matter;
- practically free of pests and damage caused by them affecting the general appearance of the produce;
- free of abnormal external moisture, excluding condensation following removal from cold storage;
- free of any foreign smell and/or taste;
- free of damage caused by low and/or high temperatures;
- practically free of signs of dehydration.

2.1.1

The apples must have colour that is characteristic of the variety and the area in which they are grown. The development and condition of the apples must be such as to enable them:

- to withstand transport and handling; and
- to arrive in satisfactory condition at the place of destination.

2.2 MATURITY REQUIREMENTS

Apples must be at a stage of development that enables them to continue the ripening process and to reach a stage of ripeness required in relation to the varietal characteristics.

In order to verify the minimum maturity requirements some parameters such as: morphological aspects, firmness and refractometric index can be considered.

2.3 CLASSIFICATION

In accordance with the defects allowed in the Annex - Maximum Allowance for Defects, apples are classified in three classes defined below:

2.3.1 "Extra" Class

Apples in this class must be of superior quality. The flesh must be sound. They must be characteristic of the variety. They must be free of defects, with the exception of very slight superficial defects, provided these do not affect the general appearance of the produce, the quality, the keeping quality and presentation in the package[2].

[1] Firmness in this context is used to indicate an appropriate level of maturity of the fruit rather than a stage of ripening and it is acknowledged to vary according to apple varieties.

[2] Skin and other defects must not exceed the limits as defined in the Annex.

2.3.2 Class I

Apples in this class must be of good quality. The flesh must be sound. They must be characteristic of the variety. The following slight defects, however, may be allowed, provided these do not affect the general appearance of the produce, the quality, the keeping quality and presentation in the package[2]:

- a slight defect in shape and development;
- a slight defect in colouring;
- slight skin or other defects (see the Annex).

2.3.3 Class II

This class includes apples which do not qualify for inclusion in the higher classes, but satisfy the minimum requirements specified in Section 2.1 above. The following defects, however, may be allowed, provided the apples retain their essential characteristics as regards the quality, the keeping quality and presentation[2]:

- defects in shape and development;
- defects in colouring;
- skin or other defects (see the Annex).

2.4 COLOURING

In all classes, in the absence of national legislation, the following colour codes may be applied except for green and yellow apple varieties:

Code	Percentage of colour
A	75% or more
B	50% or more
C	25% or more
D	Less than 25%

3. PROVISIONS CONCERNING SIZING

Size is determined by maximum diameter of the equatorial section or by weight of each apple.
For all varieties and all classes the minimum size is 60mm if measured by diameter or 90g if measured by weight. Fruit of smaller sizes may be accepted provided the Brix level of the produce meets or exceeds 10.5° Brix and the size is not smaller than 50mm or 70g.

4. PROVISIONS CONCERNING TOLERANCES

Tolerances in respect of quality and size shall be allowed in each lot for produce not satisfying the requirements of the class indicated.

4.1 QUALITY TOLERANCES

The application of the following tolerances should take into accounts that at stages following export; products may show in relation to the requirements of the standard:

a slight lack of freshness and turgidity;

for products graded in classes other than the "Extra" Class, a slight deterioration due to their development and their tendency to perish.

4.1.1 "Extra" Class

Five percent by number or weight of apples not satisfying the requirements of the class, but meeting those of Class I or, exceptionally, coming within the tolerances of that class.

Included therein shall be allowed not more than 1.0% for apples affected by decay or internal breakdown

4.1.2 Class I

Ten percent by number or weight of apples not satisfying the requirements of the class, but meeting those of Class II or, exceptionally, coming within the tolerances of that class.

Included therein shall be allowed not more than 1% for apples affected by decay or internal breakdown

4.1.3 Class II

Ten percent by number or weight of apples satisfying neither the requirements of the class nor the minimum requirements, with the exception of apples affected by decay or internal breakdown that should not be more than 2%.

Included therein shall be allowed, a maximum of 2% by number or weight of fruit which may show the following defects:

- cork like blemishing (bitter pit);
- slight damage or unhealed broken skin/cracks;
- presence of internal feeding insects/pests or damage to the flesh caused by pests[3].

4.2 SIZE TOLERANCES

For all classes of fruit subjected to rules of uniformity, 10% by number or weight of apples not meeting the size indicated on the package.

This tolerance may not be extended to include produce with a size below 50mm or 70g if the refractometric index is below 10.5°Brix.

5. PROVISIONS CONCERNING PRESENTATION

5.1 UNIFORMITY

The contents of each package must be uniform and contain only apples of the same origin, quality, size (if sized) and variety. For "Extra" Class, colour should be uniform. Sales packages (of a net weight not exceeding 5kg) may contain mixtures of varieties and sizes provided they are uniform in quality, and for each variety concerned, its origin. The visible part of the contents of the package must be representative of the entire contents except for mixed sizes and varieties.

The uniformity of apples may be measured in accordance with one of the following options:

A. By diameter:

The maximum diameter difference of apples in the same package shall be limited to:

- 5mm if the diameter of the smallest apples is less than 80mm.
- 12mm if the diameter of the smallest apple is equal to or over 80mm.

Or

B. By weight:

The maximum difference by weight between apples in the same package shall be limited to:

- 15g if the weight of the smallest apple is 90g.
- 20g if the weight of the smallest apple 90g and over but under 135g.
- 30g if the weight of the smallest apple is 135g and over but under 200g.
- 40g if the weight of the smallest apple is 200g and over but under 300g.
- 50g if the weight of the smallest apple is over 300g.

There is no size uniformity for apples packed loose in the package or sales package.

[3] This provision applies without prejudice to the applicable plant protection rules.

5.2 PACKAGING

Apples must be packed in such a way as to protect the produce properly. The materials used inside the package must be new[4], clean, and of a quality such as to avoid causing any external or internal damage to the produce. The use of materials, particularly of paper or stamps bearing trade specifications is allowed, provided the printing or labeling has been done with non-toxic ink or glue.

Apples shall be packed in each container in compliance with the Recommended International Code of Practice for Packaging and Transport of Fresh Fruits and Vegetables (CAC/RCP 44-1995).

5.2.1 Description of Containers

The containers shall meet the quality, hygiene, ventilation and resistance characteristics to ensure suitable handling, shipping and preserving of the apples. Packages must be free of all foreign matter and smell.

6. MARKING OR LABELLING

6.1 CONSUMER PACKAGES

In addition to the requirements of the Codex General Standard for the Labelling of Prepackaged Foods (CODEX STAN 1-1985), the following specific provisions apply:

6.1.1 Nature of Produce

If the produce is not visible from the outside, each package shall be labelled as to the name of the produce and may be labelled as to name of the variety, class, colour code (if used) and size/weight or the number of pieces presented in rows and layers.

6.2 NON-RETAIL CONTAINERS

Each package must bear the following particulars, in letters grouped on the same side, legibly and indelibly marked, and visible from the outside, or in the documents accompanying the shipment. For produce transported in bulk, these particulars must appear on a document accompanying the goods.

6.2.1 Identification

Name and address of exporter, packer and/or dispatcher. Identification code (optional)[5].

6.2.2 Nature of Produce

Name of the produce if the contents are not visible from the outside. Name of the variety or varieties (where appropriate).

6.2.3 Origin of Produce

Country of origin and, optionally, district where grown or national, regional or local place name.

6.2.4 Commercial Identification

- Class;
- Size (if sized);
- Colour code (if used).

6.2.5 Official Inspection Mark (optional)[5]

7. CONTAMINANTS

7.1 The produce covered by this Standard shall comply with the maximum levels of the Codex General Standard for Contaminants and Toxins in Food and Feed (CODEX STAN 193-1995).

7.2 The produce covered by this Standard shall comply with the maximum residue limits for pesticides established by the Codex Alimentarius Commission.

[4] For the purposes of this Standard, this includes recycled material of food-grade quality.
[5] The national legislation of a number of countries requires the explicit declaration of the name and address. However, in the case where a code mark is used, the reference "packer and/or dispatcher (or equivalent abbreviations)" has to be indicated in close connection with the code mark.

8. HYGIENE

8.1 It is recommended that the produce covered by the provisions of this Standard be prepared and handled in accordance with the appropriate sections of the Recommended International Code of Practice – General Principles of Food Hygiene (CAC/RCP 1-1969), Code of Hygienic Practice for Fresh Fruits and Vegetables (CAC/RCP 53-2003), and other relevant Codex texts such as Codes of Hygienic Practice and Codes of Practice.

8.2 The produce should comply with any microbiological criteria established in accordance with the Principles for the Establishment and Application of Microbiological Criteria for Foods (CAC/GL 21-1997).

MAXIMUM ALLOWANCE FOR DEFECTS

Defects Allowed		"Extra" Class	Class I	Class II
Russetting outside Calyx/ stem cavity	• smooth net-like	3% of surface area	20% of surface area	50% of surface area
	• smooth solid	1% of surface area	5% of surface area	33% of surface area
accumulation for both types of russetting should not exceed the following		3% of surface area	20% of surface area	50% of surface area
Accumulated Blemishes & Bruising: - Bruises with slight discoloration; - Scars caused by Scabs[3] (Venturia inaequalis); - other defects/blemish including healed hail marks		$0.50cm^2$	$1.0cm^2$ $0.25cm^2$ $1.0cm^2$	$1.5cm^2$[6] $1.0cm^2$ $2.5cm^2$
Stem or Calyx cracks (healed or well cured)		----	0.5cm	1cm
Maximum length of elongated shaped defects		----	2cm	4cm

Russetting can be simply described as a "brownish roughened area or streaks on the skin of the apple". In some apple varieties rusetting is a characteristic of the variety and for others a quality defect. Allowances for russetting will be applied to apple varieties that russetting is not a characteristic of.

[6] Bruising with discoloration and dark blemishes not blending with skin color are accepted in this Class.

Notes

Notes

tia
TASMANIAN INSTITUTE OF AGRICULTURE

FGT
Fruit Growers
Tasmania

Australian Government
Department of Agriculture
and Water Resources