

Processing of fresh-cut tropical fruits and vegetables: A TECHNICAL GUIDE



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FOREWORD

Fruit and vegetable production and consumption in Asia and the Pacific region have shown a marked upward trend over the past several years. Rising consumer demand in the region has come with greater awareness of food safety issues and increased need for convenience and quality. The fresh-cut produce sector has responded to these demands, and is currently at different stages of development across the region.

Assuring the safety and quality of fresh-cut produce necessitates the selection of high quality horticultural produce for processing, and the implementation of good practice during processing operations in order to maintain produce quality and assure safety of the final product.

This technical guide reviews in detail from a theoretical and practical perspective, the critical issues that must be addressed if fresh-cut products are to meet consumer and market demand for convenience, quality and safety. It provides a case study on fresh-cut processing in Thailand, and describes in detail, the fresh-cut processing of selected fruits and vegetables produced in Thailand.

The guide is written in a simple, easy-to-read format. It should be of practical value, to small processors, trainers, extension workers and non-governmental organizations (NGOs) who provide training and support to individuals engaged in the production of fresh-cut tropical produce for sale. It also provides a useful source of information for consumers of fresh-cut tropical produce.

FAO welcomes feedback from the users of this technical guide.

A handwritten signature in black ink, consisting of a long horizontal line that curves upwards and to the right, ending in a small loop.

Hiroyuki Konuma
Assistant Director-General and
FAO Regional Representative for Asia and the Pacific

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ABBREVIATIONS AND ACRONYMS

AEW	Acidic electrolyzed water
CCP	Critical control point
CFU	Colony-forming unit
DRI	Dietary reference intake
FAO	Food and Agriculture Organization of the United Nations
FIFO	First-in, First-out
GAP	Good Agricultural Practice
GC-MS	Gas chromatography-mass spectrometry
GLN	Global location number
GMP	Good Manufacturing Practice
GRAS	Generally Recognized as Safe
HACCP	Hazard Analysis and Critical Control Points
HPLC	High performance liquid chromatography
IPS	Immediate previous source
ISR	Immediate subsequent recipient
LDPE	Low density polyethylene
MA	Modified atmosphere
MAP	Modified atmosphere packaging
NACMCF	National Advisory Committee on Microbiological Criteria for Foods
NEW	Neutral electrolyzed water
NIR	Near infrared
OPP	Oriented polypropylene
ORP	Oxidation-reduction potential
PAL	Phenylalanine ammonia lyase
ppm	Parts per million
PPO	Polyphenoloxidase
PVC	Polyvinylchloride
QA	Quality assurance
RFID	Radio Frequency Identification System
RH	Relative humidity
SPME	Solid phase micro extraction
TSS	Total soluble solids
UCC	Uniform Code Council
USEPA	United States Environmental Protection Agency
USFDA	United States Food and Drug Administration
WHO	World Health Organization

Chapter I

FRESH-CUT PRODUCTS AND THEIR MARKET TRENDS

1. Fresh-cut products

Fresh-cut products are fruits or vegetables that have been trimmed, peeled and/or cut into a fully usable product, which is subsequently packaged to offer consumers high nutrition, convenience and flavour while maintaining freshness (IFPA 2001).

The market for chilled fresh-cut produce has witnessed dramatic growth in recent years, stimulated largely by consumer demand for fresh, healthy, convenient and additive-free foods which are safe and nutritious. The food industry has responded to this demand with creative product development, new production practices, innovative use of technology and skillful marketing initiatives.

Fresh-cut tropical fruits on the market today include melons, cantaloupe, watermelon, mangoes, mangosteen, rambutan, jackfruit, pummelo, papaya, durian, grapefruit, pineapples and fruit mixes. Fresh-cut salads on the market include shredded leafy vegetables and salad mixes. Fresh-cut vegetables for cooking include peeled baby carrots, baby corn, broccoli and cauliflower florets, cut celery stalks, shredded cabbage, cut asparagus, stir-fry mixes and cut sweet potatoes. Fresh-cut herbs are also marketed widely.

Growing consumer interest in international markets in new or exotic tastes has promulgated growth in the international trade of fresh-cut products. Tropical fresh-cut fruits are particularly attractive to young consumers and 'baby boomers' who consume these products as snacks. Manufacturers in many tropical countries have responded to this growing demand by producing fresh-cuts for export.

Consumers generally purchase fresh-cut produce for convenience, freshness, nutrition, safety and the eating experience. Consumer demand for these attributes has, indeed, led to considerable innovation and diversification in the fresh-cut industry. Apart from presenting the consumer with a range of options in a single package, fresh-cuts reduce wastage at the household level, in that they allow the consumer to procure only the quantities of fresh produce required, while allowing the opportunity to readily assess the quality of the produce being purchased.

Whilst the production of fresh-cut produce requires relatively little product transformation, it requires investment in technology, equipment, management systems and strict observance of food safety principles and practices to ensure product quality.

2. Trends in the United States' fresh-cut market

Healthy foods are of critical importance to the baby boomer population in the United States' market. With shifting population demographics, consumption of ethnic foods also continues to show a growth trend. A range of tropical fruits and vegetables is imported into the United States to ensure that the year-round demand for fresh produce is adequately met.

With increased dining away from home, fresh-cut products are playing an ever-increasing role in the United States' food service sector. In 2006, 27 percent of fresh-cut produce in the United States was sold in the food service sector, while 73 percent was sold in retail. Fresh-cut produce sales increased in value from US\$3.3 billion in 1999 to US\$15.5 billion in 2007 (Cook 2009). Bagged salads and cut vegetables showed a growth trend in 2008, while sales in fresh-cut fruits declined. Fresh-cut organic salads are now being mainstreamed across the United States and feeding consumer desire for healthy food and preservation of the environment. They are now widely available in restaurants and retail outlets.

A major trend in the United States' fresh-cut industry over the past two decades has been the consolidation of companies at all levels of the food chain. Food service and retail buyers have formed conglomerates around the world and food processors have also consolidated to keep up with this trend. Large processors are now supplying large retail chains, which creates tough competition for small producers. Some regional companies have consolidated to form larger companies in order to supply growing food service chains. Small locally-owned or family-owned fresh-cut processing facilities can still fill a niche where flexibility in product type and small quantities are needed for regional restaurants and grocery stores. Small processing facilities may produce minor quantities of a range of fresh-cut products in one day to fill regional needs.

3. Trends in the European Union's fresh-cut market

The European fresh-cut industry has shown exponential growth since the early 1980s. According to Rabobank (2009) consumer emphasis on convenience and healthy living is the key driver for growth in the fresh-cut fruits and vegetables sector, with retail as the major distribution channel. While the Netherlands, Switzerland, Italy and Spain have already established a market and show strong growth in the fresh-cut produce sector, Germany has yet to embrace the sector. Italy is currently emerging as one of Europe's leading fresh-cut markets, where sales of fresh-cut fruits and vegetables have been booming in recent years and are now second only to the United Kingdom in terms of value.

4. Fresh-cut trends in Asian countries

Fresh-cut produce is sold in open-air markets and food stands in many Asian countries and is increasingly being sold in supermarkets. Fresh-cut fruits, in particular, have gained popularity in urban centres of the region. Often these products are displayed without the benefits of refrigeration so their shelf-life is frequently not extended beyond the day of display.

Fresh-cut vegetables command a larger market share than fresh-cut fruits in Thailand (Sa-nguanpuag *et al.* 2007). With growing consumer demand for ready-to-eat products, the market for fresh-cut products in Thailand is likely to show a continued growth trend.

The market for fresh-cut products in Japan and Republic of Korea has shown a steady growth trend since the late 1980s and 1990s respectively (Kim 2007). While the food service industry for school meals and restaurants is the main user of fresh-cut products in these countries, demand for them has grown in retail markets. Fresh-cut vegetables for cooking constitute the largest part of the fresh-cut produce industry in both countries. Fresh-cut salads are another major category as consumers perceive them to be healthy. Fresh-cut fruits continue to show a rapid growth trend in these countries. However, with increasing demand for fresh-cuts at the retail level, the fresh-cut industry in Japan and Republic of Korea is facing challenges to extend shelf-life and enhance food safety.



Plate 1.1 Ready-to-eat fresh-cut produce on display on a market stand



Plate 1.2 Ready-to-eat papaya salad on sale in a supermarket in Viet Nam
(Courtesy of Vietnamese participants to an FAO/KMUTT training programme on Fresh-Cut Production, Bangkok, Thailand 2010)



Plate 1.3 Ready-to-cook vegetables on sale in a Vietnamese supermarket
(Courtesy of participants to an FAO/KMUTT training programme
on Fresh-Cut Production, Bangkok, Thailand, 2010)

5. Prospects for tropical fresh-cut products in developing countries

The production of traditional dishes in most developing countries necessitates a variety of fresh ingredients. The drudgery of peeling vegetables, shelling peas and trimming herbs and vegetables, and then combining these ingredients, often deters the busy housewife from preparing these traditional foods. Similarly the difficulty of peeling fruits such as pineapple, durian and pummelo and sometimes their large size deters the consumer from purchasing them. Fresh-cut processing addresses all of these issues by making products available in a convenient, easy-to-use format with minimal waste. Packs of fresh-cut fruits and vegetables are increasingly being prepared by cottage industry suppliers in many developing countries and are being sold in wet markets in response to consumer demand for produce in a ready-to-use format.



Plate 1.4 A small vendor's cart with fresh-cut produce in Bangkok
(Courtesy of Thai participants to an FAO/KMUTT training programme
on Fresh-Cut Production, Bangkok, Thailand, 2010)

Cottage industries and small vendors are still the major supplier of fresh-cut fruits and vegetables in most developing countries. Food caterers often supply fresh-cut fruit packs for school feeding programmes. Supermarkets in most developing countries produce fresh-cut fruits and non-leafy fresh-cut vegetables on site to meet consumer demand. Bagged leafy vegetables are supplied primarily by small enterprises engaged in fresh-cut production. Growth in the fast food sector and in the food service industry of many developing countries has also increased market opportunities for many small producers of fresh-cuts.

Developed countries are constantly looking for innovative products, providing potential for tropical fresh-cut fruits and vegetables to fill a gap. Food products offering new colours, flavours and textures, if creatively packaged, would be welcome additions to the fresh-cut industry in developed countries.

Equally profitable would be the sale of fresh-cut tropical fruits and vegetables in the urban centres of developing countries. The convenience of preparing traditional meals from locally-grown ingredients would preserve culinary traditions, promote the consumption of local produce and allow consumers to eat the foods they enjoy. As the fresh-cut fruit and vegetable industry has been so profitable in developed countries, it is anticipated that the same level of growth would take place in urban centres of developing countries enjoying income growth, whose citizens have less time for meal preparation.

6. Challenges for developing countries

Developing countries have experienced many demographic changes in the past two decades. With population growth, urban centres are expanding on all continents. At the same time, traditional food supply chains and food habits have been changing to keep up with these changing trends. These social changes include:

- ▶ Increases in single person households;
- ▶ Increases in middle-income populations;
- ▶ Less time for meal preparation;
- ▶ Increased demand for convenience food items;
- ▶ Increased sales of ready-to-eat meals; and
- ▶ Increases in restaurant and fast food operations.

Growth in the market opportunities for fresh-cut produce will continue, only if consumers believe that fresh-cut produce is safe and of high quality with sufficient shelf-life. Other challenges to the marketing of tropical fresh-cut produce include:

- ▶ Preserving product quality through the marketing chain;
- ▶ The inherent fragile nature of some fruit;
- ▶ Maintaining the cold chain and proper logistics;
- ▶ Adequacy of processing equipment, refrigerated storage and processing facilities;
- ▶ Availability of technology to set up processing plants and conduct research to preserve the quality of tropical fresh-cut produce.



Plate 1.5 Fruit snacks on skewers

(courtesy of Thai participants to an FAO/KMUTT training programme on Fresh-Cut Production, Bangkok, Thailand, 2010)

Tropical fresh-cut fruits and vegetables face significant challenges in entering export markets, owing to:

- ▶ Failure to meet permitted pesticide residue levels;
- ▶ Allowable levels of microbial contamination;
- ▶ Food safety standards and audit standards;
- ▶ Food laws of the importing country;
- ▶ Quality standards of the buyer (private standards); and
- ▶ Compliance with international regulations such as the Codex Alimentarius of the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO).

Compliance with these regulatory requirements is necessary in order to develop a viable export industry for fresh-cut tropical produce from developing countries. Certification programmes that guarantee the quality and safety of fresh-cut produce are critical to their entry in export markets.

7. Marketing of tropical fresh-cut products

As many tropical fruits and vegetables are less well known in developed countries, a systematic approach is needed to promote them as 'novel' products that must taste and look appealing to the consumer in developed countries.

Factors that influence the marketing success of novel tropical fresh-cut products include:

- ▶ Meeting customer needs for quality and taste;
- ▶ Meeting customer expectations for price;
- ▶ Product presentation and consumer appeal;
- ▶ Ability to respond to current social food values – organic, fair trade, health options; and
- ▶ Satisfying the labeling requirements in the country of sale.

There is a need to provide as much information as possible about the supplier of the raw material in order to promote sales in those sectors of society wanting to make a difference in developing countries.

Chapter II

TROPICAL HORTICULTURAL PRODUCE

1. Overview of tropical fruits

Tropical fruits come in a variety of shapes and sizes, with a range of specific flavours and textures. They are typically consumed when in season in tropical countries. Consumers often prefer sun-ripened fruits, with fully developed flavours.

Mangoes, papayas, pineapples, lychees, bananas and various varieties of melons have been exported by developing countries for decades. Developing countries account for 98 percent of tropical fruit production. Mangoes account for 38 percent of tropical fruit output globally, papayas account for 14 percent and avocados account for 4 percent. Pineapples remain popular at about 21 percent of the output. The so-called minor tropical fruits now account for almost 25 percent of global output and include lychees, durian, rambutan, guava and passion fruit (granadilla).

According to FAO's *Tropical fruits commodity notes*, while the dramatic increase in production of tropical fruits is now levelling off, the growth trend in the export of these fruits continues. The growing diaspora of foreign nationals in many developed countries has fuelled growth in tropical fruit consumption in these countries. For example the fruit import centre in Birmingham, United Kingdom, has been almost solely driven and managed by immigrant traders. A growing population, interest in things exotic and a trend towards healthier eating, has increased the demand for tropical fruits and vegetables across many European countries. Many popular tropical fruits require peeling and preparation for eating. They are attractive to the busy consumer if presented in a convenient package in a ready-to-eat format.

Carambola (*Averrhoa carambola*) (Plate 2.1) or five-finger star fruit, is a species of tree native to India, Indonesia and Sri Lanka. It is popular throughout the Caribbean, parts of East Asia, Southeast Asia (for example Malaysia) and in many other tropical countries. Popularly known as star fruit, carambola is crunchy, and has a slightly tart, acidic, sweet taste, reminiscent of pears and apples.



Plate 2.1 Carambola (*Averrhoa carambola*)
(Nuttakit/freedigitalphotos.net)

Guava (Plate 2.2) derived from the Arawak 'guayabo' via the Spanish 'guayaba' is a genus of about 100 species of tropical shrubs and small trees in the Myrtaceae family of myrtles; it is native to Mexico, the Caribbean, Central America and northern South America. It has a thin delicate rind which is pale green to yellow in colour at maturity in some species or pink to red in others. It has a creamy white or orange-salmon flesh with many small hard seeds. Guava has a strong, characteristic aroma.



Plate 2.2 Guava (*Psidium guajava*)
(Master isolated images/freedigitalphotos.net)

Jackfruit (Plate 2.3) is a species of the mulberry family (Moraceae) and native to Bangladesh, southwestern India, the Philippines and Sri Lanka. It is the largest tree-borne fruit in the world. The fruits can reach 36 kilograms in weight and up to 90 centimetres in length and 50 centimetres in diameter. The sweet yellow sheaths around the seeds are about 3-5 millimetres thick and have a taste similar to that of the pineapple but are somewhat milder and less juicy.



Plate 2.3 Jackfruit (*Artocarpus heterophyllus*)
(<http://en.wikipedia.org/wiki/jackfruit>)

Mangoes (Plate 2.4) are native to South and Southeast Asia and account for almost 50 percent of all tropical fruits produced worldwide. Mango production in 2004 was estimated at 26.6 million tonnes and ranked seventh in world fruit production behind bananas, grapes, oranges, apples, coconuts and plantains. The top ten mango-producing countries in 2007, based on area of production, were China, Brazil, Guinea, India, Indonesia, Mexico, Nigeria, Pakistan, the Philippines and Thailand. The top five mango-exporting countries were Brazil, India, Mexico, Peru and the Philippines. Bangladesh, the Netherlands, Saudi Arabia, the United Arab Emirates and the United States were the top five mango-importing countries.



Plate 2.4 Mango (*Mangifera indica* L.)
(Courtesy of V. Chonhenchob, Kasetsart University)

Mangoes contain essential vitamins and dietary minerals. The antioxidant vitamins A, C and E comprise 25, 76 and 9 percent of the dietary reference intake (DRI) in a 165-gram serving of mango. Mangoes also contain other nutrients such as B vitamins and essential nutrients such as potassium, copper and amino acids at reasonably good levels. Mango peel and pulp contain other phytonutrients, such as pigment antioxidants – carotenoids and polyphenols – and omega-3 and -6 polyunsaturated fatty acids.

Mangosteen (*Garcinia mangostana*) (Plate 2.5) is a tropical fruit, believed to have originated in the Sunda Islands and the Moluccas. This fruit is either dark red or purple in colour. Its thick skin houses a sweet white pulp when fully ripe. Botanically an aril, the fragrant edible flesh of the mangosteen can be described as having a sweet and tangy, citrus-like flavour and texture. A subtle mild aroma, with fewer constituents than other fragrant fruits, explains this relative mildness.



Plate 2.5 Mangosteen (*Garcinia mangostana*)
(<http://en.wikipedia.org/wiki/mangosteen>)

Papaya (Plate 2.6), fruit of the plant of the genus *Carica*, is the most economically important fruit of the Caricaceae family. Native to southern Mexico and neighbouring Central America, the papaya is now widely cultivated in tropical countries such as Brazil, Haiti, India, South Africa and Sri Lanka as well as in the Philippines and elsewhere in the Southeast Asian region. According to FAOSTAT, Brazil was by far the largest producer of papaya globally in 2007, followed by India, Indonesia, Mexico and Nigeria.

The ripe papaya fruit, with its delicate flavour, is a tasty addition to fresh-cut fruit salads or served on its own as a chilled dessert. The ripe fruit is generally eaten in the fresh form, without the peel or seeds. The unripe 'green' fruit of papaya can be eaten in the cooked form in curries and stews, or as a salad. It is also rich in pectin, which makes it suitable for use in the production of fruit jellies.



Plate 2.6 Papaya (*Carica papaya* L.)
(Courtesy of A. Villahermosa)

Papaya fruit are very delicate and soften when ripe. The leaves are the source of the meat-tenderizing enzyme, papain which can be used in marinades for tenderizing tough meat cuts.

Pineapple fruit (Plate 2.7) are found in most tropical and subtropical countries. The pineapple has its origins in Southern Brazil and Paraguay. Popular pineapple varieties such as Smooth Cayenne, Formosa, Red Spanish and Carbezona have been commercialized for decades. According to FAOSTAT, Brazil, Costa Rica, Indonesia, the Philippines and Thailand were the five leading producers of pineapples globally in 2005.



Plate 2.7 Pineapple (*Ananas comosus*)
(<http://www.wikipedia.org/wiki/image:pineapple1.jpg>)

Pineapples are the only *bromeliad* fruit in widespread cultivation. The pineapple has multiple, helically-arranged flowers, each producing a fleshy fruit pressed against the adjacent fruits, forming what appears to be a single fleshy fruit. Pineapple is eaten in the fresh form or is preserved by canning and/or juicing. It is used in desserts, salads, as a complement to meat dishes and in fruit cocktails. Although it is sweet, it also has a high fruit acid content.

The low-acid hybrid, Cayenne is the most common fresh pineapple variety sold in the United States and in European supermarkets. This variety was developed in Hawaii in the 1970s. Fresh pineapple is delicate and thus poses a challenge during shipment. Pineapples will ripen after harvest, but like bananas are chilling-sensitive and are not readily stored under refrigerated conditions.

The **pummelo** (Plate 2.8) is a citrus fruit native to Southeast Asia. It is usually pale green to yellow when ripe, with sweet white (or, more rarely, pink or red) flesh and very thick rind. It is the largest citrus fruit, 15-25 cm in diameter, and usually weighing 1-2 kg.



Plate 2.8 Pummelo (*Citrus maxima* or *Citrus grandis*)
(Courtesy of V. Chonhenchob, Kasetsart University)

Rambutan (Plate 2.9) is a medium-sized tropical tree of the family *Sapindaceae*. The fruit of this tree is probably native to Southeast Asia and is closely related to the lychee. The leathery skin of this fruit is reddish (rarely orange or yellow) in colour and is covered with fleshy green pliable spines. The fruit flesh is translucent, whitish or very pale pink, with a sweet, mildly acidic flavour. The single seed is glossy brown, 2-3 centimetres long, with a white basal scar. The seed is soft and crunchy, is edible and may be, but is not usually eaten with the pulp.



Plate 2.9 Rambutan (*Nephelium lappaceum*)
(Rawich/freedigitalphotos.net)

Sugar apple (Plate 2.10) or atis is thought to have its origins in the Caribbean. Sugar apple is also referred to as *sweetsop*. The fruit has a scaly skin, is almost round and about 10 centimetres in width. The flesh of the ripe fruit is slightly sweet and is soft in texture. Many black pips are scattered through the flesh of the fruit.



Plate 2.10 Sugar apple – atis (*Annona squamosa*)
(<http://en.wikipedia.org/wiki/sugar-apple>)

2. Overview of tropical vegetables

Vegetables generally require a great deal of preparation prior to their inclusion as ingredients in recipes for soups, stews and ethnic dishes in some countries.

Bitter melon (Plate 2.11) is a tropical and subtropical vine of the family Cucurbitaceae, also referred to as corolla or cerassie. It is among the most bitter of all vegetables. Throughout Asia, the leaves and fruit of this plant are used in soups, stir fries and teas. The original home of the species is not known, other than that it is a native of the tropics. It is widely grown in Africa, China, the Caribbean and South and Southeast Asia.



Plate 2.11 Bitter melon (*Momordica charantia*)
(<http://wikipedia.org/wiki/Bittermelon>)

Pak choi (Plate 2.12) or Chinese cabbage, also known as snow cabbage, is a leafy vegetable often used in Asian cuisine. This vegetable is related to the western cabbage and is of the same species as the common turnip. It is one of the most well-known vegetables and is also one of the oldest green vegetables in Asia. The leaves are green, mild flavoured and less crisp than other cabbages. It is often used in stews and soups.



Plate 2.12 Pak choi (*Brassica chinensis*)
(http://en.wikipedia.org/wiki/chinese_cabbage)

Chayote (Plate 2.13) whose common names include Cho-cho, or Chouchou, is a yellow-green or white, pear-shaped vegetable. It has a wrinkled scabby skin, with greenish-white flesh. The chayote is believed to have its origins in Central America. More common varieties of this vegetable are pear- or apple-shaped, and are somewhat flattened with coarse wrinkles, ranging from 10 to 20 centimetres in length. The flesh is fairly bland in taste, and has a texture described as being a cross between that of a potato and a cucumber.



Plate 2.13 Chayote (*Sechium edule*)
(<http://en.wikipedia.org/wiki/chayote>)

Pumpkin (Plate 2.14) (*Cucurbita maxima*) or squash is a vegetable that is cultivated throughout Southeast Asia; it can be cooked with or without the skin. The colour of the skin can vary from green to yellow. The flesh is deep yellow to orange in colour. Pumpkins are soft in texture and are sweet. They are rich in vitamin A and are consumed as side dishes or as ingredients in bakery products.



Plate 2.14 Pumpkin (*Cucurbita maxima*)
(Courtesy of E. Esguerra, UPLB)

3. Overview of edible stems

Ginger (*Zingiber officinale*) (Plate 2.15) is a monocotyledonous perennial plant. The term ginger is also used to describe the edible part of the plant which is commonly used as a spice in cooking throughout the world. Erroneously referred to as 'ginger root', the edible section is actually the horizontal subterranean stem or rhizome of the plant. The ginger plant has a long history of cultivation known to have originated in China; it later spread to India, the Caribbean, Southeast Asia and West Africa.



Plate 2.15 Ginger (*Zingiber officinale*)
(<http://en.wikipedia.org/wiki/ginger>)

In 2005, China continued to lead the world in ginger production with a global share of almost 25 percent followed by India, Indonesia and Nepal.

Heart of palm (*palmito, pajibaye*) (Plate 2.16) also referred to as palm heart, palmito, chonta, or swamp cabbage, is a vegetable harvested from the inner core and growing bud of certain palm trees (coconut, palmito, juçara [*Euterpe edulis*], açai palm [*Euterpe oleracea*] etc.). It is costly because harvesting in the wild kills the tree. Heart of palm is often eaten in salads. It is sometimes referred to as the 'millionaire's salad' and is also used in vegetarian spreads.



Plate 2.16 Heart of palm (*palmito, pajibaye*)

(http://en.wikipedia.org/wiki/heart_of_palm)

When harvesting the cultivated young palm, the tree is cut and the bark is removed leaving layers of white fibres around the centre core. During processing the fibres are removed leaving the centre core or heart of palm. The centre core is attached to a slightly more fibrous cylindrical base with a larger diameter. The entire cylindrical centre core and the attached base are edible. The centre core is considered more of a delicacy because of its lower fibre content.

Sugar cane (Plate 2.17) is a genus (*Saccharum*) of up to 37 species, depending on the taxonomy, of tall perennial grasses (family Poaceae, tribe Andropogoneae) that are native to warm temperate to tropical regions. They have stout, jointed, fibrous stalks that are rich in sugar and measure 2 to 6 metres in height. The edible portion of sugar cane is the inner stalk (stem) the sap of which is a source of sugar. The thick stalk stores energy as sucrose in the sap. The sap can be extracted by pressing the sugar cane stalk.



Plate 2.17 Sugar cane (*genus Saccharum*)

(http://commons.wikimedia.org/wiki/Image:Cut_sugarcane.jpg)

From this juice, crystallized sugar is extracted by evaporating the water. As of 2005, the world's largest producer of sugar cane by far was Brazil. Uses of sugar cane include the production of crystal and liquid sugar, molasses, rum and ethanol for fuel.

CHAPTER III

FRESH PRODUCE QUALITY AND SAFETY

1. Fresh produce quality

Quality is a combination of characteristics that determines the value of produce to the consumer. Consumers expect fresh produce to be without defects, of optimum maturity and in fresh condition. The condition of fresh fruits and vegetables relates to their general appearance, sensory quality, flavour and nutritional quality (Watada and Qi 2000; Kader 2002). Consumers judge the quality of fresh fruits and vegetables based on their appearance and firmness (external attributes). Subsequent purchases by consumers are, however, dependent on their eating experience (aroma, taste, texture intrinsic or experience attributes). Other quality parameters like nutritional quality and safety (hidden attributes) increasingly influence consumer decisions on making repeated purchases of the commodity. Only fruits of the highest quality should be used for fresh-cut processing.

2. Components of fresh produce quality

Quality attributes are often classified as external, internal or hidden. External quality attributes are visual when the product is first encountered. These attributes are generally related to 'appearance' and 'feel'. Internal quality characteristics are sensed when the product is cut or bitten. Internal attributes include aroma, taste and feel (for example, 'mouth-feel' and 'toughness'). Hidden quality attributes include wholesomeness, nutritional value and safety of the product.

Appearance quality

The visual quality of fruits and vegetables relates to their size, shape, colour, glossiness, cleanliness of the surface and absence of defects or signs of spoilage. Fresh produce defects include evidence of: bruising and crushing of pieces, shrivelling and wilting due to water loss, mushiness or tissue softening, colour changes due to enzymatic browning or physical disorders, sliminess and water soaking due to ageing. Spoilage also induces changes in appearance, such as mushiness owing to mould growth and package swelling due to the release of gases by bacteria or unattractive colour changes (Kader 2002).

Texture quality

Texture (*feel*) relates to the feel of the produce item in the hands or in the mouth. Textural attributes can be described in the context of firmness or hardness, crunchiness, crispness,

tenderness, juiciness, mealiness and toughness, depending on the commodity. The textural quality of horticultural produce is not only important for its eating and cooking quality, but also for its transportability through the horticultural chain.

Flavour quality

Flavour (eating) relates to the taste and smell (aroma) of the produce. Flavour attributes can be described as the perception of tastes and aromas coming from many sources including sugars for sweetness, the acidity of organic acids such as citric acid in oranges and lemons, the bitterness and astringency of phenolic compounds and tannins, and aromas from volatile compounds. Most fruits and vegetables have sweet, sour and bitter tastes but little or no salty and umami¹ tastes.

Good flavour is an important guarantee for repeat purchasing of fruits by consumers. Consumers are generally willing to pay more for desirable flavour (Ragaert *et al.* 2004). Growth of spoilage microorganisms can lead to off-odour or flavour development, as occurs when fresh produce begins to ferment (Kader and Mitcham 1999).

Eating quality

The eating quality of fresh produce results from complex interactions between texture and flavour and effects on the nutritional value (Kader 2002).

Nutritional quality

Fruits and vegetables are well-known sources of useful nutrients in the form of vitamins, minerals, dietary fibre and other phytonutrients including flavonoids, carotenoids and phenolic compounds that may lower the risk of cancer, heart disease and others illnesses (Kader 2002). Consumption of fresh fruits and vegetables is encouraged and a recommendation of at least five servings per day has been made to American consumers.

Safety

Safe food is free of physical and chemical hazards or microorganisms that cause adverse effects to human health and life. Safety is a component of quality. Many experts are of the view that safety is the most important component of quality, since unsafe food can result in serious injury and even death. Business loss and a poor image as a result of legal action are also serious consequences of consuming unsafe food.

The safety of fresh produce can be compromised by *physical hazards* such as glass, dust and insects or chemical hazards such as pesticides or microbiological hazards resulting from poor sanitation or bad hygienic practice in the producer to consumer chain.

Biological hazards refer to pathogenic microorganisms that cause human illnesses directly when consumed together with the produce (infection) or by producing toxins or chemical substances harmful to humans in the produce before it is consumed. In some cases, the microbial population may be insufficient to cause produce decay but may be enough to cause human infection or

¹ Similar to, but not the same as savoury.

intoxication after the produce has been consumed. Thus, produce that is perfect in appearance is not guaranteed to be microbiologically safe. Pathogenic microorganisms can contaminate the produce through the soil, contaminated water, badly treated manure, sewage, air, poor worker hygiene or contaminated surfaces of post-harvest facilities such as produce packages, transport and storage facilities.

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

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

3. Evaluation of quality

Quality evaluation methods can be both destructive and non-destructive. They include objective methods, based on the use of instruments and subjective methods, based on human judgement. Instruments may be designed to imitate human-testing methods. Fundamental mechanical measurements may be statistically related to human perceptions and judgements to predict quality categories. Quality can only be judged by consumers. Instruments that measure quality-related attributes are vital for research and inspection.

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

Objective measurements of quality employ the use of instruments (e.g. colorimeter for colour, firmness tester for texture) and are suitable for routine quality control but cannot measure consumer preferences. The only way to assess consumer preferences for fruits and vegetables is by sensory testing and asking panellists to provide their opinions/assessment on the fresh produce item. Sensory evaluation is not, however, suitable for routine use and the best way of assuring quality is to find objective measurements that correlate to sensory attributes.

Evaluation of appearance and colour

Colour perception depends on the type and intensity of light, the chemical and physical characteristics of produce and the ability of an individual to perceive the colour. Colour is measured using subjective and objective methods.

Subjective methods of colour measurement rely on the human eye. A colour index is formulated and is matched with a colour chart that corresponds to the developmental stages of a specific produce item. Colour indexing and colour chart matching are, however, prone to human error because of differences in colour perception. Trained panelists may be required to reduce the bias. The light exposure and quality of light at the time of measurement may also affect colour perception.

A **colorimeter** is used for the objective measurement of colour and can detect small differences in colour. Obtaining colorimetric measurements is however costly and more time consuming than using colour indices.

Evaluation of taste and flavour

Sugar is the main component of total soluble solids (TSS) in most fruits and vegetables. Measurement of TSS, therefore, provides a reasonable indicator of sugar levels or sweetness. TSS is measured using either a refractometer or a hydrometer. The former operates on the basis of the refraction of light by juice samples and the latter on the basis of the density of the juice. Both methods are 'destructive', only needing a few drops of sample juice for measurement.

Acidity is generally measured by titration with a suitable alkaline solution such as sodium hydroxide or by measuring the pH using a pH meter. Certain acids can be individually measured by high performance liquid chromatography (HPLC). Light reflectance in near infrared (NIR) has been applied as a non-destructive method for measuring sugar levels in mangoes, melons and kiwi fruit.

Sensory studies can be used to identify optimal harvest maturity, evaluate flavour quality in breeding programmes, determine optimal storage and handling conditions, assess effects of disinfestations or preconditioning techniques on flavour quality and measure flavour quality over the post-harvest life of a product. Sensory difference testing can be used to measure slight differences in the aromas of produce. Panelists are trained to detect a range of flavour attributes and score their intensities, generally on a 150-millimetre unstructured line.

Laboratory measurements are conducted by headspace analysis using gas chromatography and purge and trap headspace sampling methods that involve trapping and concentrating volatile components on a solid support. Volatiles are later released from the trap using heat for analysis by gas chromatography-mass spectrometry (GC-MS). This method is excellent for quantification and identification of aroma compounds.

Solid phase micro extraction (SPME), a rapid sampling technique wherein volatiles interact with a fibre-coated probe inserted into sample headspace is also applicable in sensory assessment. The probe is transferred to a GC injection port where the volatiles are desorbed. Aside from GC and GC-MS methods, new sensors with a broad range of selectivity are used in headspace analysis. These sensor arrays, referred to as 'electronic noses', are useful in discriminating reactions of volatile components.

Evaluation of texture

According to Meilgaard *et al.* (1999), texture is a consequence of four major properties:

- ▶ Surface properties: surface moistness or wetness;
- ▶ First bite properties: springiness, hardness, denseness, crispness, juiciness and uniformity of bite;
- ▶ Chew down properties: chewiness and cohesiveness; and
- ▶ After swollen properties: mouth coating, toughness.

Texture is generally determined on the basis of measurements of force applied to a food sample. The firmness of fresh-cut produce is, in many instances, a fairly good indicator of textural properties. The most common method of texture measurement is the puncture test which is conducted with the use of a penetrometer such as the Magness-Taylor firmness tester or the Effegi penetrometer.

The penetrometer measures the total force required to puncture through a given portion of the fruit or vegetable to a standard depth using a probe of specified diameter. The rate of loading should be controlled and specified in mechanized measurements. The optimal rate of loading differs for different commodities.

Compression tests are not commonly used by the fruit and vegetable industry; they are widely used in research. They can be made on cylindrical tissue specimens excised from the fruit or on intact products using a variety of contact geometries.

4. Factors that impact on fresh produce quality

The pre-harvest quality of produce is influenced by the cultivars, genotypes and rootstocks, climate, cultural practices, maturity and ripening (Kader 2002).

Pre-harvest factors

Cultivar: Genetics are the key to the flavour, texture, post-harvest life and susceptibility of fresh fruits and vegetables to enzymatic browning (Garcia and Barrett 2002). The selection of appropriate cultivars is, therefore, of critical importance in assuring the quality characteristics of fruit destined for fresh-cut processing.

Climatic factors: Climatic factors and the environment in which crops are produced have a significant impact on the eating quality and shelf-life of fresh produce. Temperature and light intensity pre-harvest influence the make-up and nutritional quality of fruits and vegetables. The location and growing season may influence the levels of ascorbic acid, carotene, riboflavin etc. High levels of rainfall increase the susceptibility of the plant to mechanical damage. Low light intensity generally results in reduced levels of ascorbic acid (vitamin C) in plant tissue.

Temperature influences the uptake of minerals by plants during transpiration. The strength of the sun's radiation is known to affect produce texture. Excessive exposure of tomatoes to excessive

sunlight can, for example, result in sunscald or sunburn. Intense sunlight can increase fruit temperatures and results in fruit damage and loss of firmness (Sams 1999).

Cultural practices: Cultural practices such as pruning and trimming enhance crop load and the size of fruit. Fruit maturity may be affected by the use of pesticides and growth regulators. Soil quality with respect to nutrient composition has an immediate impact on developing fruit and on texture (Sams 1999), appearance and taste (Kader 2002). Kader and Mitcham (1999) reported that a lack of calcium during cultivation often resulted in tissue softening after harvest. Bachmann and Earles (2000) reported that produce that has been stressed by too much or too little water, or high rates of nitrogen, was particularly susceptible to post-harvest diseases.

The impact of cultural practices on food safety is now widely recognized. A number of outbreaks of foodborne illnesses have been traced to contamination of produce in the field (Bachmann and Earles 2000). Improper use of manure and contaminated irrigation water can transfer pathogens onto crops, resulting in human disease. Raw manure should never be applied to edible crops. Good Agricultural Practice (GAP) must therefore be applied in order to mitigate contamination risks to produce during production.

Harvest factors that impact on fresh produce quality

The maturity of fruits and vegetables at harvest determines their quality. Immature fruit may lack flavour and are susceptible to disorders. Apart from affecting the flavour, maturity at harvest also has a direct effect on the texture of fresh produce. Immature fruits contain pectic materials, known as protopectins, of very high molecular weight. On ripening, the chain length of the pectic polymer decreases and water-soluble pectins are formed. This results in textural changes in the fruit, leading to a soft and mushy consistency (Bourne 1983). Overripe fruits are highly susceptible to damage during cutting and are thus unsuitable for fresh-cut processing.

Many fruits are harvested at the mature but unripe stage of development in order to ensure best eating quality. Climacteric fruits such as bananas, guavas and papayas continue to ripen after harvest. These fruits can be ripened by exposure to ethylene. Other fruits such as pineapples, oranges, lychees and muskmelons must be harvested when mature because no further ripening and flavour development occurs.

Kader and Mitcham (1999) suggested that fully mature fruit in which metabolic activity is in decline are at an optimal stage for harvest given that post-harvest changes occur more slowly and storage life is improved. Ripe and fully ripe fruit tend to develop a desirable taste with the onset of starch to sugar conversion, as occurs in bananas and mangoes for example. Astringency due to a high level of tannins also tends to decline at this time. Watada and Li (1999) noted that the quality of young honeydew melon cubes with 8.8 percent soluble solids was lower than that of more mature fruits with 13 percent soluble solids after storage. Beaulieu and Baldwin (2002) found that the aroma of fresh-cut cantaloupe increased with harvest maturity.

Vegetables are generally of optimal eating quality prior to reaching full maturity. Vegetables that are not harvested at the correct stage of maturity are generally of lower quality and undergo rapid deterioration after harvest.

Post-harvest factors that impact on fresh produce quality and safety

Quality after harvest is influenced by handling and the management of relative humidity and temperature conditions. Quality loss results from factors that are both internal (physiological processes) and external (microbiological, chemical, environmental and mechanical) to harvested produce. Respiration and transpiration are physiological processes that can be greatly influenced by environmental conditions such as temperature, relative humidity, the composition of the gaseous environment and mechanical or physical damage to the produce.

Microbial and chemical contamination can greatly compromise the safety of horticultural produce. Microbial contamination can be transmitted through improper cultural practices, by unsanitary worker practice and through contact with soil and unclean surfaces. Mechanical injury can accelerate the loss of water and vitamin C and can increase susceptibility to decay by pathogenic microorganisms (Kader 2002).

Maintaining quality after harvest necessitates proper handling to avoid mechanical and physical injury and the avoidance of chemical and microbiological contamination. Produce must also be stored under optimal conditions of temperature and relative humidity. Ethylene-sensitive commodities such as leafy vegetables, herbs and watermelons must be stored in the absence of ethylene and away from high ethylene producers such as cantaloupes, peaches and tomatoes.

5. Maintaining the quality of fresh produce between harvest and processing

Harvesting to assure quality and safety

Quality is influenced by maturity at harvest and the methods of harvesting, storage times, temperatures and extent of handling. Produce should ideally be harvested during the cooler part of the day, on the day of processing, in order to minimize storage and handling and thus increase fresh-cut shelf-life. Field staff should be trained in proper harvesting methods so as to prevent damage to the produce. Fruit should be physically mature, with flavour developing for best taste. Produce with insect damage, sun scorch or any other physical damage would not produce good quality fresh-cut products with the desired shelf-life. Reducing defects also reduces the microbial load associated with the produce.

Field workers must use the appropriate harvesting equipment and protective containers in order to prevent damage to produce during harvesting.

Post-harvest handling to assure quality and safety of fresh produce

Harvested produce should be placed in a shaded area so as to avoid sun damage if awaiting transportation to the processing plant. Produce must be properly handled to avoid bruising and contamination.

Pre-cooling

Pre-cooling is the rapid removal of field heat from fresh produce. It is among the most efficient quality enhancements available to commercial producers and ranks as one of the most essential value-added activities in the horticultural chain. Proper pre-cooling can:

- ▶ Prevent quality loss due to softening by suppressing enzymatic degradation and respiratory activity;
- ▶ Prevent wilting by slowing or inhibiting water loss;
- ▶ Slow the rate of produce decay by slowing or inhibiting microbial growth (fungi and bacteria);
- ▶ Reduce the rate of ethylene production; and
- ▶ Minimize the impact of ethylene on ethylene-sensitive produce.

Plate 3.1 shows two methods for removing field heat from vegetables before storage.



Ice and water injection



Vacuum cooling tunnel

Plate 3.1 Removal of field heat from bulk vegetables

(Images published with permission of Boskovich Farms, Inc., California, USA. www.boskovichfarms.com)

Washing and disinfection

Any dirt on the surface of produce must be thoroughly removed by washing in water. The produce must be subsequently washed in potable water containing a sanitizer in order to reduce the risk of the transfer of microbial contamination during processing.

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

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

Sanitizer treatment: Post-harvest handling and sanitation treatments have considerable impact on the microbiological quality of fresh-cut produce. Washing whole fruits and vegetables in clean water only achieves an insignificant reduction in microbial populations. The use of sanitizers such as chlorine, peroxyacetic acid, hydrogen peroxide, acidified sodium chloride or ozone can provide an additional 1-2 log reduction in the initial population (Heard 2002) of microorganisms on the surface of fresh produce.

Chlorine is currently the most commonly used sanitizer in washing operations. Chlorine has been successfully used at concentrations ranging from 50 to 200 parts per million (ppm) to wash fruits in fresh-cut fruit studies (Ayhan *et al.* 1998; Beaulieu and Gorny 2002 Ukuku and Sapers 2001; USFDA 2001) and fresh-cut mango studies (Martínez-Ferrer *et al.* 2002; Chantanawarangoon 2000). Improper use of chlorine can, however, lead to the retention of a faint chlorine odour on the fresh-cut fruit.

Despite its common use as a disinfectant for decontamination of fresh produce, chemical hazards associated with chlorine or chlorine residues are of concern. The use of chlorine in the processing of minimally processed products has been banned in some European countries (Day 2001; Varoquaux and Mazollier 2002).

Alternatives to chlorine

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

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

Acidified sodium chlorite (ASC, NaClO_2): This is a chlorine-based sanitizer synonymous with SANOVA® and forms chlorous acid ($\text{NaClO}_2 + \text{H}^+ - \text{HClO}_2$), which has strong oxidizing capacity. Chlorous acid further breaks down to chlorite. This sanitizer has been approved by the USFDA and the United States Environmental Protection Agency (USEPA) for application on fruits and vegetables, including fresh-cut produce, by spraying or dipping in 500-1 200 ppm solution.

Ozone (O_3): This is a water-soluble gas with broad and rapid biocidal activity. It has strong oxidizing capacity and high reactivity and penetrability. It is, however, unstable under ambient temperature conditions. Ozone rapidly undergoes spontaneous decomposition under conditions of high pH

(pH >8) leading to the production of oxygen which is a non-toxic product. Ozone must be generated on site from air.

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

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

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

CHAPTER IV

FRESH-CUT PROCESSING: PHYSIOLOGICAL AND MICROBIOLOGICAL IMPACTS

Fresh-cut processing involves peeling, trimming and deseeding fresh produce and cutting it to specific size (Figure 4.1). Fresh-cut products must not only look fresh, but must have the sensory properties – aroma, taste, texture and visual appeal – associated with freshly prepared produce. Thus only fresh produce of good quality must be used as the starting material in fresh-cut processing. Fresh-cut products must also be safe, wholesome and nutritious.

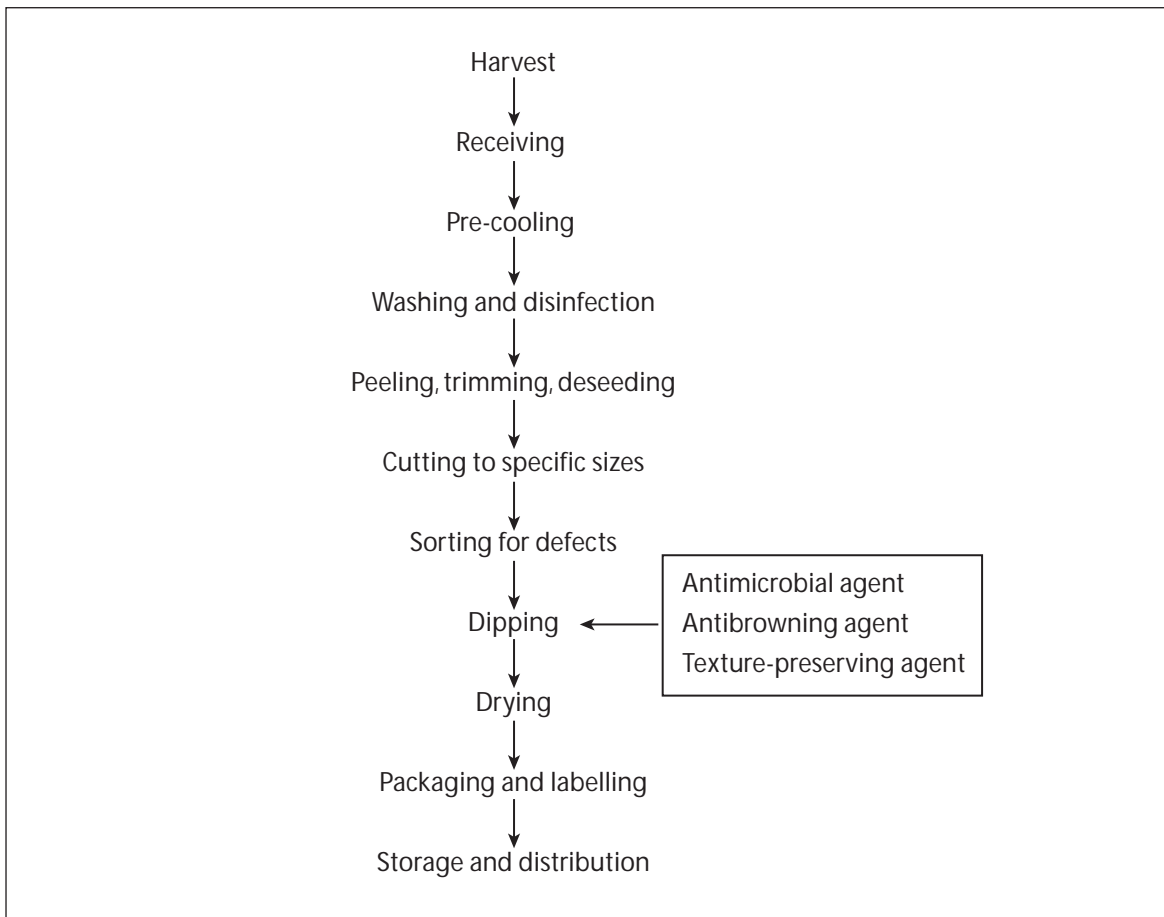


Figure 4.1 Typical fresh-cut process flow chart for fruits, vegetables and root crops

1. Physiological effects of fresh-cut processing

Fresh-cut processing involves cutting through the tissue of fresh produce, thus causing major tissue disruption and the release of enzymes that interact with substrates associated with the fruit tissue. Wounding of the fruit tissue by cutting also increases ethylene production and stimulates respiration and phenolic metabolism. Phenylalanine ammonia lyase (PAL), an enzyme that catalyses the formation of phenolic compounds, is stimulated by ethylene production (Figure 4.2). Phenolic compounds in turn serve as substrates for polyphenoloxidase enzymes which, in the presence of oxygen, eventually lead to the formation of complex brown polymers.

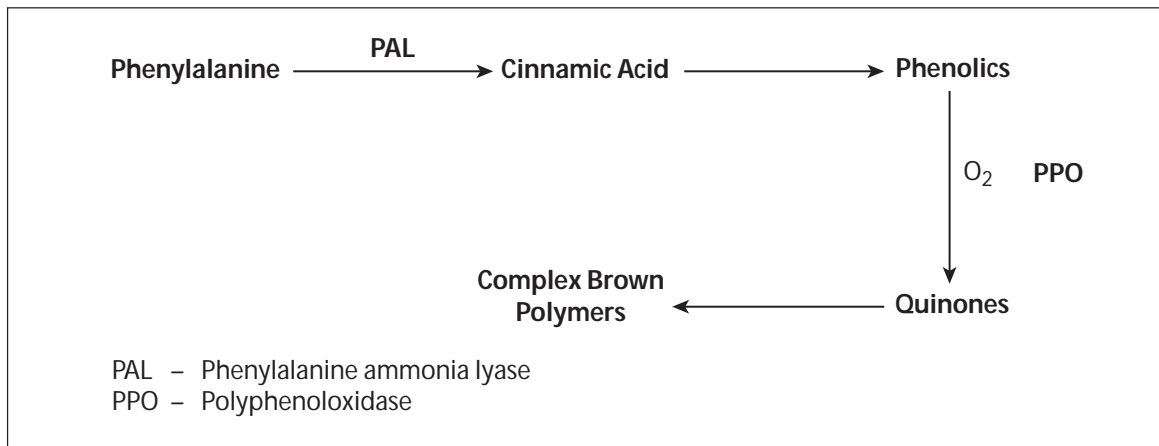


Figure 4.2 Steps in phenolic metabolism that result in browning

Increased respiration rates result in water loss and a reduction in the levels of carbohydrates, vitamins and organic acids, with a net negative impact on flavour and aroma. Water loss is also enhanced by membrane and cell wall degradation, and results in loss of turgor. At the same time, microbial growth at the cut surface also increases as sugars become available, thus accelerating the opportunity for microbial spoilage.

2. Biochemical changes brought about by fresh-cut processing

Colour change

Browning or surface darkening is one of the main physiological effects of fresh-cut processing and leads to quality loss in fresh-cut produce. It is the result of oxidation of phenolic substrates present in the produce by PPO enzymes (McEvily *et al.* 1992). The extent of browning is dependent on the concentrations of active PPO and phenolic compounds in the produce tissue, pH, temperature and oxygen available to the tissues as well as on the presence of antioxidant compounds (Kader 2002). High levels of PPO enzymes are generally found in tissues that are rich in phenolic compounds. Levels of PPO and PPO substrates change during the life cycle of fruits and vegetables.

Carotenoids, a yellow pigment in fruit and vegetable tissues, are highly susceptible to oxidative breakdown that is catalysed by lipoxygenase enzymes. Yellowing of green vegetables such as

broccoli and spinach reduces their quality and shelf-life. Dehydration of surface debris on cut and peeled carrots results in a translucent appearance, referred to as 'white blush', which reduces their market appeal.

Flavour quality changes

Key components of flavour in fresh fruits are sweetness, acidity, astringency and bitterness. Many flavour and aroma components are lost in fresh-cut fruits through enzymatic reactions brought about by cutting, and through the increased respiration rates of the fruit tissue.

Microbial spoilage also contributes to flavour degradation in fresh-cut products. Fresh-cut products can acquire off-flavours with the growth of lactic acid bacteria or *pseudomonads*, resulting in fermentation and the production of acids, alcohols and carbon dioxide gas (CO₂). Lipase enzymes and the breakdown of amino acids in fruits by microorganisms can contribute to the alteration of fruit flavours.

Changes in nutritional quality

Vitamins A, B6, C, thiamine, niacin, minerals and dietary fibre all contribute to the nutritional quality of fresh fruits and vegetables. Compounds such as flavonoids, carotenoids, polyphenols and other phytonutrients associated with reducing the risk of cancer and heart disease are also found in plants. According to Gil *et al.* (2006), fresh-cut fruits and vegetables can appear visually spoiled before any nutrient loss occurs. In the future, plant-breeding techniques may be used to create cultivars with improved nutritional attributes that are able to withstand the effects of processing.

Texture quality changes

The unprotected cut surface of fresh-cut fruits loses moisture at an extremely rapid rate. Such high rates of water loss result in rapid wilting and shrivelling of fresh-cut produce and thus a loss of the crisp, firm texture of the product. Tissue softening of fresh-cut produce during storage is the result of structural changes in the primary cell walls; this is caused by enzymatic activity that leads to dissolution of the rigid pectic cells and a decrease in their resistance to pressure. Decreased rigidity due to water loss is the main cause of tissue softening in fresh-cut fruits.

While there is a paucity of data on the effects of fertilizer on fresh-cut fruit quality, too much nitrogen is known to reduce firmness, while high levels of potassium and calcium can improve fruit quality at harvest.

3. Quality loss due to microbial contamination

Fresh-cut vegetables harbour lower numbers of microorganisms than unwashed whole vegetables, as a result of washing in chlorinated water. Slicing, dicing and shredding procedures, as well as temperature abuse during storage, can, however, result in increases in populations of mesophilic aerobic microorganisms (Brackett 1992; Nguyen-the and Carlin 1994) associated with fresh-cut products. The effects of processing and storage conditions on the survival and growth of pathogenic microorganisms on fresh-cut produce is a public health concern.

Microbes associated with fresh-cut fruit and vegetable products can vary greatly in accordance with the produce type and storage conditions. Temperature plays a significant role in determining the nature of the microflora associated with refrigerated fresh-cut fruits and vegetables. The numbers and kinds of microorganisms associated with fresh-cut produce are highly variable. Mesophilic bacteria from plate count studies typically ranged from 10³ to 10⁹ CFU/g. Total counts on products after processing ranged from 10³ to 10⁶ CFU/g (Nguyen-the and Carlin 1994).²

Vegetables are susceptible to attack by bacterial pathogens owing to their neutral pH. Spoilage of fresh-cut vegetables by bacteria is characterized by brown or black discoloration, production of off-odours, loss of texture and soft rot. Fruit products undergo fermentative spoilage by lactic acid bacteria or yeasts and wilting owing to vascular infections (Heard 2000).

4. Spoilage organisms associated with fresh-cut produce

Pseudomonads: The family Pseudomonadaceae consists of the four genera: *Pseudomonas*, *Xanthomonas*, *Zoogloea* and *Frauteuria* (Palleroni 1992). The role of pseudomonads as spoilage organisms is well known. Pseudomonads contribute to the spoilage of fresh produce by producing tissue-degrading enzymes such as pectolytic cellulases, xylanases, glycoside hydrolases and lipoxygenase that degrade the cell walls of the plant tissue, resulting in maceration of the plant tissue. *Pseudomonads* may also contribute to the yellowing of vegetable products during storage, through the production of ethylene.

Pseudomonads are commonly isolated from fresh-cut vegetable salads. *Pseudomonas fluorescens* are generally the main species associated with the spoilage of leafy vegetables such as fresh-cut spinach and lettuce. Other *Pseudomonas* species associated with fresh-cuts include *Pseudomonas putida*, *Pseudomonas chloraphis*, *Pseudomonas corrugata*, *Pseudomonas cepacia*, *Pseudomonas paucimobilllis*, *Pseudomonas marginalis* (*P. fluorescens* biotype II) and *Pseudomonas viridflava*. Predominant species reported on vegetables such as broccoli, endive and sprouts include the fluorescent *Pseudomonads* and species of *Klebsiella*, *Serratia*, *Lavobacterium*, *Xanthomonas*, *Chromobacterium* and *Alcaligenes*. *Pseudomonas. Syringae* and *Pseudomonas stutzeri* were isolated from stored fresh-cut Thai mango (Ngarmsak *et al.* 2005). These plant pathogens occur on many plant species and can contribute to the spoilage of fresh produce when their populations exceed 10⁸ CFU/g.

Lactic acid bacteria: These are gram-positive bacteria, which can be both rods and cocci. They are traditionally known as fermentative organisms and are associated with fermented food products and with food spoilage. There are three main groups: the *Lactobacillus delbrueckii* group, which includes mainly homofermentative lactobacilli; the *Lactobacillus casei/Pediococcus* group; and the *Leuconostoc* group (Heard 2000). The habitats of species of the genera *Lactobacillus* and *Leuconostoc* include plants and plant material, soil, water, sewage, fruit and grain mashes. Their fermentative metabolism and ability to grow under anaerobic conditions enable lactic acid bacteria to cause spoilage, such as souring of the product, gas production and slime formation. Fresh produce items that are susceptible to spoilage by lactic acid bacteria include lettuce, chicory leaves and carrots.

² CFU = colony-forming unit.

Yeast and moulds: Fruits are frequently affected by fungal pathogens because of their relatively high levels of acidity (low pH) while vegetables are susceptible to attack by bacterial pathogens because they are neither acidic nor basic, but are at a neutral pH. In some instances, specific plant pathogenic fungi may be associated with particular forms of spoilage such as the breakdown of tissues. Moulds are aerobic microorganisms and can, therefore, be inhibited at CO₂ concentrations as low as 10 percent.

Pathogenic organisms

Food-borne pathogens known to contaminate fresh-cut products include bacteria, viruses and parasites such as protozoa. Of these, bacteria are of the greatest concern in terms of reported cases and gravity of illness. Although not their natural habitat, most fruits and vegetables contain nutrients required to support the growth of pathogenic and toxigenic microorganisms. Storage temperature and pH are reported to be the two principal determinants of growth for food-borne pathogens associated with fresh produce.

Psychrotrophic bacteria, which are organisms that can grow under conditions of refrigeration, vary widely in their acidic tolerances and are the most important spoilage group for fruits and vegetables. The most important of these from a food safety point of view are *Listeria* and *Clostridium*. The fact that these organisms can grow at refrigerated temperatures makes them very important from an export perspective.

Fresh-cut vegetables can be occasionally contaminated with food-borne pathogenic bacteria such as *L. monocytogenes* (Sizmur and Walker 1988) and *Salmonella* spp. (O'Mahony *et al.* 1990).

Good Manufacturing Practice (GMP) and food safety systems such as Hazard Analysis and Critical Control Points (HACCP) must be applied in the production of fresh-cut fruits and vegetables if they are to be recognized as being safe.

Listeria monocytogenes: This is a gram-positive bacterium that causes listeriosis, a serious disease in pregnant women, the elderly and those with weakened immune systems. *L. monocytogenes* is widespread in the environment (i.e. in soil, water and decaying vegetation). It has been isolated from the intestinal tract of domestic animals and humans, from raw produce and in food-processing environments particularly in cool damp areas. It can survive and grow under both ambient and refrigerated temperatures. There are reports describing survival of the organism and formation of biofilms on surfaces in food-processing environments, particularly in drains. It may also be transmitted by aerosols and on workers' hands.

Listeria monocytogenes has been isolated from pre-packaged mixed vegetable products, chicory, endive and fresh-cut lettuce, sliced cucumber and fruits such as tomatoes and cantaloupe. It has also been implicated in food-borne disease outbreaks across the globe.

Salmonella: *Salmonella* is a common cause of food-borne illness (salmonellosis) and is responsible for millions of cases of illness each year. Fresh produce may become contaminated with salmonellae through contact with sewage and contaminated water or through handling by infected workers. *Salmonellae* do not grow in foods stored at temperatures lower than 7°C.

Salmonella should, therefore, not pose a risk to public health in fresh-cut products, provided these products are maintained at or below 7°C.

Typical symptoms of salmonellosis are nausea, vomiting, abdominal cramps, fever, mild diarrhoea and headache. These symptoms generally last over six to 48 hours.

***Clostridium botulinum*:** This is a spore-forming bacterium. The spores of *C. botulinum* are commonly found in agricultural soils and on the surfaces of fruits and vegetables; they generate potent neurotoxins that produce a range of symptoms in humans including nausea, diarrhoea and vomiting and neurological symptoms such as blurred vision, dilated pupils, paralysis of motor nerves, loss of normal mouth and throat functions, lack of muscle coordination, other complications and possible death. *C. botulinum* spores are capable of growing on fresh-cut vegetables under conditions of low O₂ and high temperature (Sugiyama and Yang 1975).

***Shigella spp.*:** Humans are a natural reservoir for *Shigella* spp. The primary means of transmission of the *Shigella* organism is by the fecal-oral route. Most cases of infection by *Shigella* (shigellosis) are attributed to the ingestion of food or water contaminated with fecal matter. Contamination has often been associated with poor personal hygiene of food workers. Typical symptoms include abdominal pain, cramps, diarrhoea, fever, vomiting and blood, pus, or mucus in stools. Shigellosis outbreaks have been associated with shredded lettuce, potato salad, green onions and parsley.

***Escherichia coli*:** It is reasonable to believe that as a result of substandard or even illegal agricultural practices, produce may be contaminated with human pathogens such as *E. coli*. The National Advisory Committee on Microbiological Criteria for Foods (NACMCF) in the United States lists 11 agents associated with produce-borne outbreaks. Foremost among them are *Escherichia coli* O157:H7 and various *Salmonella* serotypes.

Control of food-borne pathogens

Control of food-borne pathogens must begin before produce is even planted, by avoiding fields that have been subjected to flooding, on which animals have recently grazed or have been contaminated with manure. After planting, only clean potable water should be used for irrigation and harvesting equipment should be thoroughly cleaned and sanitized. Both field workers and packing-house and processing-plant personnel should be instructed in proper personal hygiene and provided with adequate sanitary and hand-washing facilities. Vehicles transporting finished products should be sanitized, properly loaded to provide adequate air circulation and maintained at appropriate temperatures. Likewise, retail display cases must be kept clean and at appropriate chilled temperatures. Finally, consumers should be informed as to proper hygienic handling of produce.

Chapter V

STRATEGIES FOR MINIMIZING QUALITY LOSS AND ASSURING SAFETY DURING FRESH-CUT PROCESSING

Fresh-cut processing of fruits and vegetables represents a paradox in food science. Unlike other processes applied to food products, the unit operations applied to fresh commodities during fresh-cut processing tend to decrease shelf-life, rather than enhance the stability of the product (Chantanawarangoon 2000).

This Chapter discusses strategies for maximizing quality and assuring safety during fresh-cut processing operations.

1. Minimizing mechanical damage and microbial contamination during cutting

The quality and status of equipment used for peeling and cutting is critical in fresh-cut processing operations. Use of the sharpest cutting tools will extend product shelf-life. Dull utensils have been proven to cause excessive cell damage and bruising leading to poor quality. Severe peeling and cutting must be avoided.

Cantwell (1998) studied the impact of blade sharpness on the quality of fresh-cut melons stored at 5°C. The results indicated that melon chunks cut with a dull blade were susceptible to a translucence disorder, increased leakage and high ethanol concentrations in the package (Portela and Cantwell 2001). Pear slices cut with a freshly sharpened knife retained their visual quality longer than fruit cut with a dull hand slicer (Gorny and Kader 1996). O'Beirne (2007) showed that slicing with a blunt blade enhanced the penetration of fresh-cut carrots by *E. coli* and its subsequent survival during storage. Frequent sharpening of machine and hand knives and proper cleaning and sanitizing of processing equipment and surfaces that come in contact with fresh-cuts is clearly a key control point in fresh-cut fruit processing.

2. Minimizing transfer of contamination during washing operations

Many large fresh-cut processing operations treat and recycle water in order to conserve this precious commodity. Care must be taken in recycling water so as not to introduce new risks of increased microorganisms to produce during washing. It is recommended that the best quality water be used for the final rinse of intact fruits and vegetables prior to fresh-cut processing.

Many operations inject chlorine as a disinfectant along with acid in order to maintain a pH range of 4.5-5.5 and assure the effectiveness of chlorine during washing operations. Measurement and recording of the chlorine level and the pH of wash water is a critical element of any quality assurance programme. When used to reduce the temperature of wash water, ice should be routinely tested in order to ensure that it is not a source of contamination.

The disinfectant level in wash water can be monitored through the measurement of oxidation-reduction potential (ORP). ORP is a measure of the oxidation level in the water in millivolts, and gives an indication of the efficacy of a sanitizer during processing. The stronger the oxidation, the faster the microbes are killed. Variables that affect antimicrobial activity during processing directly affect the ORP value and may also be used to determine the effectiveness of oxidizers such as hypochlorous acid, hypobromous acid, chlorine dioxide, ozone and peroxides.

Water quality can be maintained by:

- ▶ Closely following mixing directions for sanitizers;
- ▶ Using test strips or instruments to routinely measure sanitizer levels and pH;
- ▶ Removing debris; and
- ▶ Filtering wash water before recycling.

3. Temperature management during processing operations

Temperature control is essential at each step of a fresh-cut fruit process, in the distribution chain and in retail. Low temperature storage helps to slow the respiration rate, maintain quality and prolong shelf-life by keeping product temperature at the point where metabolic activity and microbial deterioration are minimized. Low temperature storage slows the growth of mould and bacteria. Thus the ideal storage temperature for each commodity should be researched carefully. Temperature is the most important factor in the preservation of fresh-cut fruit quality. The rates of chemical and biochemical reactions that affect quality are largely determined by temperature.

Heat and low temperature are both used in the pre-treatment of whole fruits and vegetables prior to fresh-cut processing in order to increase shelf-life (Lamikanra *et al.* 2005). Mild heat treatment of whole apples before processing resulted in the retention of firmness during storage in some fresh-cut apple cultivars. Low temperature pretreatments such as the hydrocooling of asparagus spears and baby corn reduced respiration rates, reduced toughening of the texture and prolonged the quality of fresh-cut products.

Heated wash water treatments were shown to reduce pathogens on mango fruits (such as 'Nam Dok Mai'). Mangoes treated with 100 ppm chlorine at 50°C had virtually no retention of aerobic bacteria on fruit skin and fresh-cut samples (Ngarmsak *et al.* 2005).

Many fruits of tropical or subtropical origin are sensitive to low temperatures (Paull 1990). These fruits are injured after a period of exposure to chilling temperatures below 10 to 15°C, but above their freezing points. At these temperatures, fruit tissues are weakened owing to their inability to carry out normal metabolic processes. Various physical and biochemical alterations and cell

malfunctions occur in response to chilling stress. When chilling stress is continued, these alterations and malfunctions lead to the development of a variety of chilling injury symptoms, such as surface lesions, internal discoloration, water-soaking of the tissue and failure to ripen normally (Saltveit and Morris 1990, cited in Wang 2004).

A number of fresh-cut fruit products, exhibit less sensitivity to chilling injury (CI) than intact fruits (Siripanich 2000; Paull and Chen 2004). The reasons why peeled tissue tolerates lower temperatures are unclear, but the degree of ripeness may play a role. Ripe fruit has been known to tolerate low temperatures better than unripe fruit (Siripanich 2000).

Cantwell (1998) drew the following conclusions regarding the handling of fresh-cut products that are sensitive to chilling injury:

- ▶ It is important that intact chill-sensitive produce is not stored below the recommended storage temperature, before being prepared as a fresh-cut product.
- ▶ Once a chill-sensitive commodity is prepared as a fresh-cut product, storage at low temperature is needed to retard microbial growth and ensure quality.
- ▶ Microbial changes take place more rapidly than the appearance of any symptom of chilling injury.
- ▶ For chill-sensitive commodities, temperature and controlled atmosphere suitable for the intact produce are often not suitable for fresh-cut pieces.

4. Post-cutting treatments designed to extend the shelf-life of fresh-cut products

A number of physical and chemical treatments designed to delay physical decay processes in the tissues and to extend the shelf-life of fresh-cut fruits and vegetables have been developed and tested. Chemical methods rely on the inhibition of specific reactions that generate undesirable changes. Physical methods include reductions in temperature and/or oxygen concentration, the use of modified atmosphere (MA) and the application of heat or high pressures.

Chemical post-cutting treatments

Wounding and ethylene can initiate phenolic metabolism that ultimately leads to browning in fresh-cut tissue. Control of discoloration (pinking, reddening or blackening) or browning at cut surfaces is, therefore, a critical issue for fresh-cut producers. Outlined below are a number of strategies that may be used to reduce cut-surface discoloration and maintain the textural integrity of fresh-cut produce.

Acidification: PPO most effectively catalyses cut-surface discoloration at a neutral pH (around pH 7.0). Browning can, therefore, be slowed by dipping products in mildly acidic food grade solutions of acetic, ascorbic, citric, tartaric, fumaric or phosphoric acid. Quite often, combinations of acids (for example combinations of ascorbic and citric acid) are more effective than the use of acids individually. However, these acids may impart off-flavours or promote tissue softening, and must, therefore, be used with care.

Reducing agents: Reducing agents such as ascorbic acid or the erythrostate isomer of ascorbic acid are commonly used in the food industry to prevent PPO-mediated cut-surface discoloration. Ascorbic acid and erythrostate reduce PPO-induced discoloration at cut-surfaces by converting quinones (formed by PPO from phenolics) back into phenolic compounds. Once all of the ascorbic acid or erythrostate is exhausted, PPO browning will proceed uninhibited. Ascorbic acid or erythrostate are commonly used in solution at a concentration of 1 μ M. Given their acidic nature, they may also reduce the surface pH of commodities, further slowing the rate of browning.

Application of edible coatings: The application of edible coatings such as sodium caseinate or stearic acid may be helpful in reducing white blush in vegetables such as carrots. Treatments that modify the water-retaining capacity of the cut surfaces also prevent white blush development.

Natural antimicrobials: Some plant extracts, such as ginger, marigold and cinnamon, exhibit antimicrobial activity. Cinnamon extract at 500 ppm was shown to control banana crown rot. Chitosan, a polysaccharide extracted from chitin, a natural substance in the shells of shrimp and crab has been shown to be effective in controlling rambutan fruit rot (*Lasiodiplodia theobromae*), mango anthracnose, banana crown rot and *Botrytis cineria* in strawberries. The application of vanillin as a dip at a concentration of 80 mN and storage at 5°C were effective in reducing the microbial populations in fresh-cut mangoes (Ngarmsak *et al.* 2006).

Firming agents: The firmness of the flesh of fresh-cut fruit products can be maintained through the application or treatment with calcium compounds. Dipping fresh-cut products in solutions of 0.5 to 1.0 percent calcium chloride was shown to be very effective in maintaining product firmness (Ponting *et al.* 1971; 1972). Calcium ions form cross links within pectin chains, resulting in stronger cell walls. Calcium chloride treatments can, however, result in bitter off-flavours in some products.

Physical post-cutting treatments

Reduced oxygen: As PPO requires oxygen in order to induce cut-surface discoloration, reducing the oxygen levels in a fresh-cut product package by vacuum, modified atmosphere packaging (MAP) or gas flushing may reduce cut surface discoloration; however it does not completely stop it. Careful design of fresh-cut packaging is essential to assure the levels of oxygen within the package. While excessive levels of oxygen in a package may lead to discoloration of cut surfaces, inadequate levels may cause anaerobic metabolism, resulting in the production of off-flavours and odours.

MAP: Technologies continue to be developed in order to enhance the shelf-life of fresh-cut fruits and vegetables. Modified atmosphere and low temperature storage have been used for many years to reduce respiration rates and the deterioration of fresh-cut produce. MAs by definition are atmospheres that differ in composition from that of normal air. MAs can be generated passively or actively. In many developing countries, fresh-cut produce is generally packed in film bags or plastic containers overwrapped with film. A passive modified atmosphere is created within the package by the respiration process of the fresh-cut produce, combined with the permeability of the package. An active MA can be achieved by flushing with a particular gas or mixture of gases to create an initial atmosphere or by incorporating additives such as oxygen scavengers into the packaging.

Typically, MAs consisting of low oxygen and high CO₂ concentrations are used to reduce respiration rates and ethylene production in fresh-cut products. Such conditions can also be applied to prevent browning of the cut surface, retard enzyme activity and to inhibit microbial growth. A successful MAP design requires the determination of respiration rate and respiration quotient (Al-Ati and Hotchkiss 2002). The choice of appropriate polymer films with suitable permeability and appropriate film area; together with headspace volumes and knowledge of produce respiration characteristics, is essential. Excessive depletion of oxygen in the package can result in anaerobic respiration that leads to the formation of off-flavours.

Given the high respiration rate of fresh produce, hazardous anaerobic conditions and undesirable fermentation reactions can occur within packages of fresh-cut produce when stored under conditions of high temperature. During the retail of modified atmosphere packages, temperature fluctuations are unavoidable. The application of high oxygen concentrations (70 percent) could, however, overcome the disadvantages of low oxygen modified atmosphere packaging, for some ready-to-eat vegetables. High levels of oxygen are particularly effective in inhibiting enzymatic discoloration, preventing anaerobic fermentation reactions and in inhibiting microbial growth. It has been hypothesized that high oxygen levels may cause substrate inhibition of PPO, or alternatively, that high levels of colourless quinones subsequently formed may cause feedback inhibition of PPO.

Heat treatment: Heat treatments have been noted to improve tissue firmness in fresh-cut fruits such as apples slices (Kim *et al.* 1993) and mango cubes (Banjongsinsiri *et al.* 2004; Trindade *et al.* 2003; Kim *et al.* 1993) found that heating whole apples at 45°C every 30 minutes for a two-hour period before slicing improved the texture of apple slices as compared to untreated apples, but this improvement depended upon the cultivar.

A 90-second heat-shock at 104°F (45°C) prevented wound-induced browning of iceberg lettuce (Loaiza-Velarde *et al.* 1997; Loaiza-Velarde and Saltveit 2001; Saltveit 2000). A low heat treatment to activate the enzyme pectinesterase prior to a CaCl₂ dip was helpful in preserving fresh-cut fruit texture. Pectinesterase is known to de-esterify pectin, thereby increasing the number of calcium binding sites (Garcia and Barret 2002).

Chapter VI

PRACTICAL ASPECTS OF FRESH-CUT PROCESSING

1. The fresh-cut chain: harvest to market

When preparing fresh-cut fruits and vegetables and root crops, the key steps of the chain: harvesting, receiving, pre-cooling, washing and disinfecting, peeling and trimming, cutting into specific sizes, sorting for defects, washing and cooling, packaging/labelling and storage and distribution. A typical flow chart of activities in the chain is shown in Figure 4.1.

Harvesting

Individuals engaged in fresh produce harvesting must be trained in the selection of fresh produce of sound quality. Produce must be handled in such a way as to avoid damage and contamination. Handlers must ensure that only the best quality produce is selected for fresh-cut processing. Management should supply all the equipment needed to minimize damage of fruits and vegetables during harvest, for example sharp harvesting knives, bags and padded boxes. Workers must wear clean clothes and observe sanitary measures.

Mechanical harvesters are used in large operations to take handling closer to the source in the field, improving shelf-life and maintaining produce quality.



Plate 6.1 In-field processing of fresh-cut vegetables
(Images used with permission from Boskovich farms Inc., www.boskovichfarms.com)

Receiving at the processing facility

The receiving point for fresh fruits and vegetables in a fresh-cut processing plant is a key quality check-point that should be monitored closely. Employees receiving produce should check for defects and make note of any problems that can be relayed to the grower. At this point a decision can be made on whether or not to process the produce. Large processing operations have a list of quality parameters and measurements that are recorded when fresh produce arrives at the processing facility. An inventory of stocks begins with receipt of the produce. Large processing facilities usually have an enclosed, refrigerated dock facility for receiving produce.

Table 6.1 shows an example of a quality assurance (QA) checklist for raw material received at the fresh-cut processing plant. Recording as much information about the produce as possible would help to trace it back to the field in the event of a food crisis. Thus field number, harvest crew, vehicle registration and other information can be recorded when produce is received at the back door of a fresh-cut processing plant.

Table 6.1 Quality Assurance checklist for raw commodities received at the packing house

Harvest area (number/field#):			Date/time:		
Harvest crew:			Supervisor:		
Vehicle registration:			Bin label:		
Commodity	Parameter	Result	Specifications	Corrective actions	Initials
Size					
Brix					
Colour					
Acidity					
Defects					
Temperature					

Pre-cooling

Ideally, produce should be cooled to remove field heat prior to storage or processing. Cooling extends the shelf-life of the final fresh-cut product. Large fresh-cut processing operations make use of any of a number of technologies such as chilled water baths, forced air cooling, vacuum cooling and packing with ice-water mixtures, for removing field heat from fresh produce.

While small operations may not be able to afford expensive cooling equipment, storing produce in a refrigerated area is adequate for cooling small quantities of produce. Care should be taken to note temperatures below which chilling injury of various fruits and vegetables would take place. While this research has been conducted for many temperate produce items, it is still not widely known for some tropical fruit and vegetables.

Intact fresh produce should be segregated in a small cold storage area to avoid cross contamination between it and that which has been pre-cut and washed. Staff should use a First-in, First-out (FIFO) policy for managing stock rotation.

Washing and disinfection

It is important to wash produce as soon as possible after harvest to remove damaged tissues. Water flumes and tanks are used in large operations to wash fresh produce prior to cutting and trimming (Plate 6.2). Potable water is a key requirement for washing in order to preclude the transfer of contamination from water to the produce.



Plate 6.2 Water flume for washing and transporting fruit in a large packing house
(Image used with permission from Boskovich farms Inc., www.boskovichfarms.com)

Many large fresh-cut processing operations treat and recycle water to conserve this precious commodity. Care must be taken in recycling water so as not to present a new risk of increased microorganisms. Recycled water must be continuously treated and monitored. In situations where the organic material in wash water increases, the antimicrobial agent HOCl loses its effectiveness in maintaining water quality.

In very small operations, washing in a sink or under a tap with running water is appropriate. Produce may also be washed at a small scale in large shallow tanks that allow operators to move the produce freely through the water. In situations where concrete tanks are used they should ideally be tiled. Frequent changes of wash water are needed in order to effectively remove soil and other foreign matter from the produce. A better method is to continuously circulate wash water through a filter. Ideally several tanks should be used for washing operations. The first tank should be used for the removal of heavy soiling and subsequent cleaner tanks with chlorinated water should be used for final washing.

Large fresh-cut processing plants make use of continuous washers (Plate 6.3). In such situations, a moving conveyor picks up the produce and carries it under powerful sprays of water. Recirculation through a filter reduces overall water consumption. The temperature, contact time, pH and chlorine concentration should be monitored for their effectiveness during washing. The measurement of ORP can also be used to monitor the disinfectant level in wash water.



Plate 6.3 Continuous washing of pre-cut lettuce

(Image used with permission from Boskovich farms Inc., www.boskovichfarms.com)

For vegetable wash water the following parameters may be used: temperature (0-5°C), pH (4.5-5.5), chlorine concentration (50-100 ppm), ORP (650-750 ppm). During the washing process any defective produce must be removed and discarded.

Peeling, trimming and deseeding

In small processing plants, knives are used to trim and peel fresh produce. Large processing plants make use of abrasive peelers and automated trimmers to accelerate the process. Available funding would determine whether a small processor could use technically advanced peelers and trimmers during operations. Automated peelers with abrasive rollers are used in some large processing plants for peeling potatoes and carrots. Machinery has been designed for specific high volume crops, including the use of high pressure air and lye and steam for peeling. However, for small operations, hand peeling is adequate (Plate 6.4).

Cutting operations

Produce may either be chopped, sliced, shredded, peeled, diced or sectioned. These operations are done mainly by hand in many small-scale operations. The dimensions of the finished product are determined by the end use identified for each produce item. Chopping boards and knives are used to create the desired size and shape for finished products. Research has shown that using a sharp



Plate 6.4 Workers preparing and sorting cut fruit
(Courtesy of A. Hicks)



Plate 6.5 Workers in complete food safety attire
(Image used with permission from Boskovich farms Inc., www.boskovichfarms.com)

knife reduces physical damage to cut fruits and vegetables in that less stress is observed in the cells of produce cut with a sharp knife. Staff should ensure all knives and chopping boards are cleaned and sanitized before use so as to minimize the potential for contamination. Good Hygienic Practice (GHP) must be strictly observed during cutting operations.

Employees involved with cutting operations should be properly attired with protective clothing, including gloves, aprons and hair nets. They should be well trained in the preparation of products to minimize damage. Products should receive minimal handling to avoid bruising and contamination due to excessive handling. Whatever the method of cutting, the sizing of the produce must be uniform; given that non-uniformly sized products are not appealing to consumers.

Sorting for defects

Defective products may also hasten spoilage and decrease shelf-life. Removal of defects improves uniformity of the finished fresh-cut product and enhances shelf-life.

Rinsing of pre-cut fruits and vegetables

It is recommended that only water of the highest quality be used for the final rinse of pre-cut fruits and vegetables. Many operations inject chlorine as a disinfectant along with acid in order to maintain a pH range of 4.5-5.5 and to assure the effectiveness of chlorine. Measurement and recording of the chlorine level and the pH of wash water is therefore a critical element of any quality assurance programme. Ice used for reducing the temperature of water should be routinely tested in order to ensure that it is not a source of contamination.

Dipping

Produce can be optionally dipped in a solution of an acidulant/antioxidant blend consisting of a combination of ascorbic acid/citric acid for example, or in an anti-softening agent such as calcium chloride.

Drying

Excess water or liquid associated with the produce must be removed prior to packaging of fresh-cut products. Water in the finished product encourages mould growth and the growth of other microorganisms resulting in rapid deterioration of texture. Various manual and mechanical methods have been developed for the removal of excess water from fresh-cut fruits and vegetables. These include:

- ▶ Use of conveyor shakers to remove water through a mesh. The cut fruit or vegetable vibrates on the conveyor mesh.
- ▶ Air drying on conveyors with forced air or polar wind used to blow excess water off the surface of the wet produce.
- ▶ Spin-drying baskets, both automated and manual, that make use of centrifugation to remove excess water.

Packaging/labeling

Packaging facilitates the delivery of fresh-cut products of good quality to the consumer. Packaging protects products from physical damage and prevents physical and microbiological contamination. Packaging can on some occasions, as in the case of MA, delay spoilage of products. Cut fruits and vegetables deteriorate more rapidly than intact or packaged products.

Attention must be paid to the compatibility of produce, where mixed fruit and vegetable combinations are packaged. Ethylene-sensitive and ethylene-producing fruits should not be mixed, as this could result in water soaking and rapid deterioration of ethylene-sensitive produce.

Packaging formats for fresh-cut fruits and vegetables (Plate 6.6) include plastic bags, thermoformed containers with film overwraps and rigid plastic containers. Packs are filled by hand in small



(1) Leafy Vegetables packaged in breathable bags (Courtesy of V. Chonhenchob, Kasetsart University) **(2) Clamshell tray with hinge interlock** (Courtesy of V. Chonhenchob, Kasetsart University) **(3) Clear PET tray with an overwrap film** (Courtesy of V. Chonhenchob, Kasetsart University) **(4) Zip lock bags used in small-scale operations** (Courtesy of A. Hicks)

Plate 6.6 Examples of packaging used for fresh-cut fruits and vegetables

operations, while automated equipment is used in larger operations. A metal detector is generally positioned at the end of the line in automated operations and bags of products pass through the detector as a control measure to test for metal contaminants. Finished product containers are labelled with a 'Use By' date to alert customers of the optimum product shelf-life. Other company codes may be printed on the package.

MAP reduces the respiration rate of produce and thus slows the rate of spoilage. In addition, it creates anaerobic conditions or high carbon dioxide and low oxygen levels in the pack, to extend fresh produce shelf-life. Oriented polypropylene (OPP) is generally used in the MAP of fresh-cuts. Other packaging films used include perforated, thin, low density polyethylene (LDPE), monolayer polyvinylchloride (PVC) and ethylene vinyl acetate.

2. Managing and measuring quality during fresh-cut operations

Consumer acceptance of fresh-cut produce is influenced by colour, texture, aroma and taste. Convenience is a major reason for the procurement of fresh produce by consumers. Consumers choose fresh-cuts based on freshness, price and packaging. Their eating experience (aroma, taste, texture) determines whether consumers will continue to purchase such products.

Quality parameters for fresh-cut lettuce
<ul style="list-style-type: none">▶ Fresh appearance;▶ No decay; no contamination;▶ No discoloration;▶ Crisp texture;▶ Good aroma and flavour.

A well-managed quality assurance programme should be developed to ensure that only the finest quality product leaves the fresh-cut processing plant. Management must develop specifications for the product at every stage of the fresh-cut processing chain: raw materials, in-process products and finished products. Monitoring programmes for storage and transport (temperature, relative humidity etc.) should also be developed. When raw material enters the plant, its quality determines the quality of the final product. Quality assurance findings should be documented and corrective actions taken if products do not conform to specifications.

Quality assurance systems

Product quality is a prime criterion for gaining access to competitive markets. Quality control ensures that raw materials and finished products are handled, stored, processed or packaged to the required quality standards. The fundamental purpose of a quality assurance programme is to have timely and dependable information on all the attributes of a product which affect its quality. The basic functions of a quality assurance programme include:

- ▶ Physical, chemical and sensory evaluation of raw materials and fresh-cut products;
- ▶ In-process control of raw materials and fresh-cut products:
 - raw materials, ingredients and packaging supplies
 - processing parameters
 - finished products
- ▶ Microbiological analysis and control of raw materials and finished products;
- ▶ Control of storage and handling conditions;
- ▶ Control of sanitation and waste products;
- ▶ Assurance that final products are within the established legal and marketing standards.

Quality as a synonym for food safety can be used as a tool for marketing fresh-cut products in countries with high food safety standards. Product quality can be maintained throughout the supply chain by applying good practice. Methods for measuring each quality parameter should

be clearly outlined, for example instrumentation and testing procedure. Staff should be assigned to monitor quality and to record the results of quality checks in daily log sheets. Management should verify daily log sheets to ensure that only products that meet specifications are packaged.

Raw material quality assessments might include:

- ▶ Measurement of the sugar content (degrees Brix);
- ▶ Measurement of the pH and organic acid content;
- ▶ Pressure testing to assess softness;
- ▶ Measurement of the colour at harvest;
- ▶ Observation for defects; and
- ▶ Verification that the product's shape is ideal for processing.

In-process quality measurements include measurements to ensure:

- ▶ Size of fresh-cut pieces are within specification;
- ▶ Products are mixed in correct proportions, if applicable;
- ▶ Products are free from excess water – measure the spin-drying cycle; and
- ▶ Product temperature is cool enough to promote product quality – measure and record temperature in the process.

Finished product quality measurements include assessment of:

- ▶ Packaging integrity;
- ▶ Average weight of packages;
- ▶ Label printing;
- ▶ Best Before/Use by dates and production dates are correct on the label; and
- ▶ The package temperature is adequate to sustain quality.

3. Managing and maintaining quality during marketing

Fresh-cut fruit produce that is not produced on site is either transported on ice or in refrigerated trucks. Air transportation is used where markets are distant, primarily overseas markets. The fresh-cut products are normally transported in closed containers or netted/stretched film-wrapped pallet loads. The potential for temperature abuse and losses in quality are high during marketing and are a critical consideration.

Quality loss is a function of both time and temperature. If products are neglected, even for short periods at high temperatures during loading and off-loading, the shelf-life is reduced. Refrigeration removes excess heat and facilitates temperature control for fresh-cut produce during storage and transportation. Maintaining the 'Cold Chain' is the key to delivering wholesome fresh-cut products to the end user.

Fresh-cut fruits must be stored at the lowest temperature possible to maintain their freshness and minimize losses. In view of the fact that fresh-cut products are under severe physical stress during

processing, they should be held at a lower temperature than that recommended for uncut commodities. The optimal storage temperature for fresh-cut produce is, in general, set as the minimum required to minimize microbial growth while preventing chilling injury.

Relative humidity (% RH) is an indication of the balance between the water evaporated from the stored produce and its removal from the air by evaporating fans of the refrigeration system. RH levels of 80 to 90 percent are generally recommended to prevent a build-up of condensation that attracts mould and mildew in the cold room. Factors to consider when storing produce are the quantity of product to be stored; the type and method of packaging; stacking patterns to promote air circulation, air motion; system running time; and the power of the refrigeration unit. A still cold storage would take a longer time to cool products than one with fans to keep air circulating.

4. Assuring safety in the fresh-cut processing chain

Fresh-cut produce is highly vulnerable to contamination during processing. Every effort must, therefore, be made to minimize the risk of contamination in the producer–consumer chain. Factors in minimizing risk in the production–consumption chain are summarized below:

Harvesting and post-harvest handling

- ▶ Cleaning and sanitizing harvesting equipment;
- ▶ Excluding wild birds and animals from packing houses;
- ▶ Avoiding cross contamination during delivery to the processor; and
- ▶ Minimizing cutting and bruising.

Fresh-cut processing

- ▶ A programme for sanitizing surfaces and machines;
- ▶ Good preliminary decontamination and inspection;
- ▶ Avoiding severe peeling/cutting;
- ▶ Eliminating/minimizing human contact with processed products;
- ▶ Effective washing/anti-microbial dipping; and
- ▶ Avoiding post-dipping contamination.

Packaging/distribution/retail

- ▶ Careful selection of packaging material;
- ▶ Monitoring microbial quality of packaged products;
- ▶ Ensuring that the temperature is <4°C;
- ▶ Modest shelf-life labeling;
- ▶ Suitably-designed vehicles
- ▶ Proper vehicle loading practices;
- ▶ Chill cabinet loading; and
- ▶ Education of retailer and consumer.

5. HACCP for effective running of a fresh-cut plant

From 1988 to the present day, HACCP principles have been promoted and incorporated into food safety legislation in many countries around the world. The approach was originally derived from Engineering System's – 'Failure Mode and Effect Analysis'. It was further developed by Pillsbury/NASA for the American Space Programme. HACCP reduced the risk of astronauts suffering from the effects of consuming contaminated food whilst in space. It is a food safety methodology that relies on the identification of Critical Control Points (CCPs) in food production and preparation processes. Closely monitored CCPs will ensure that food is safe for human consumption.

HACCP is used to avoid the antiquated approach of testing the finished product without knowing the risks involved in preparation.

The HACCP system consists of seven principles:

Principle 1: Conduct a hazard analysis. Three main categories of hazards: biological, chemical and physical, may affect products. Management should determine the food safety hazards and identify the preventive measures that can be applied by the plant to control these hazards.

Principle 2: Identify CCPs, the steps or procedure in a food process at which control can be applied. The result is prevention of a food safety hazard or reduction to an acceptable level.

Principle 3: Establish critical limits for each CCP. A critical limit is the maximum or minimum value to which a physical, biological or chemical hazard must be controlled at a critical control point to prevent, eliminate or reduce to an acceptable level.

Principle 4: Establish CCP monitoring requirements. Monitoring activities are necessary to ensure that the process is under control at each critical control point.

Principle 5: Establish corrective actions. These are actions to be taken when monitoring indicates a deviation from an established critical limit. The final rule requires a plant's HACCP plan to identify the corrective actions to be taken if a critical limit is not met. Corrective actions are intended to ensure that no product injurious to health or otherwise adulterated as a result of the deviation, enters commerce.

Principle 6: Establish record-keeping procedures – a written HACCP plan and records documenting the monitoring of critical control points, critical limits, verification activities and the handling of processing deviations.

Principle 7: Establish procedures for ensuring that the HACCP system is working as intended. *Validation* ensures that the plans do what they were designed to do; that is, they are successful in ensuring the production of safe products. Plants will be required to validate their own HACCP plans. *Verification* ensures that the HACCP plan is adequate and is working as intended. Verification procedures may include such activities as a review of HACCP plans, CCP records, critical limits and microbial sampling and analysis.

In developing an HACCP plan, the whole process must be evaluated for possible risks. A HACCP flow chart would show the CCPs and a decision-making tree would be used to determine which hazard may actually be controlled and measured. Figure 6.1 shows the typical HACCP flow chart for a fresh-cut fruit processing operation. CCPs of final rinse water and metal detection can be monitored and controlled if they are out of specification. This is the requirement for a hazard to qualify as a CCP.

Chapter VII

EQUIPMENT REQUIREMENTS FOR FRESH-CUT PROCESSING

Fresh-cut processing can be performed at different scales of operation. Regardless of the scale of operation, individuals engaged in fresh-cut processing should be properly attired with protective clothing, including gloves, aprons and hair nets. They should be well trained in the preparation of products to minimize damage, excessive handling and contamination.

Equipment must be cleanable, properly maintained and sanitized prior to use. Surfaces that come in contact with the food must be non-toxic, non-reactive with the produce, non-contaminating to the produce, non-corrosive and cleanable. Stainless steel of the 300 series is preferred for food contact surfaces (Turatti 2007).

1. Equipment for fresh-cut processing

Equipment for fresh-cut processing should be designed and constructed such that it is easy to clean and maintain, thus minimizing the potential for microbial contamination of the fresh-cut product.

The USFDA recommends the use of smooth, non-absorbent, sealed and easily cleanable food contact surfaces that are sloped to drain freely and made of durable, non-corrosive, non-toxic materials for fresh-cut processing. Food contact surfaces include items such as knives, conveyors, belts, chutes, product totes, gloves, tools including shovels and racks, cutting boards, tables, driers and spinner baskets as well as packing scales. All food contact surfaces should be smoothly bonded (i.e. free of pits, folds, cracks, crevices, open seams, cotter pins, exposed threads and hinges) to avoid harbouring pathogens. Where two food contact surfaces meet, a cover over the juncture should be used to prevent food debris from collecting in the crevice and creating an area that is difficult to clean.

Equipment for small-scale manual operations

Requirements for a small processing plant include sharpened knives, plastic cutting boards, stainless steel or plastic bowls and tubs for storing trimmed products prior to cutting or packaging (Plate 7.1). These simple kitchen utensils are easy to obtain.



Plate 7.1 Standard kitchen equipment for the small fresh-cut processor

Mechanical equipment for the processing of fresh-cut leafy vegetables

Many fresh-cut processing plants for leafy vegetables use automated equipment for all stages of fresh-cut processing. These include the following items of equipment:

- ▶ Product bin dumpers (Plate 7.2);
- ▶ Elevator belt conveyors;
- ▶ Automatic sorting machines;
- ▶ Abrasive peelers or high pressure water peelers;
- ▶ Trans-slicers or other cutting machines (Plate 7.3);
- ▶ Continuous washing conveyors (Plate 7.4);
- ▶ Spin driers, air driers, shakers (Plate 7.5);
- ▶ Form-fill-seal packaging machines;
- ▶ Weighing, labelling, coding machines (Plate 7.6);
- ▶ Boxing and palletizing machines;
- ▶ Metal detectors (Plate 7.7).



Plate 7.2 Product bin dumper
(Image published with permission of
Boskovich Farms, Inc., California, USA.
www.boskovichfarms.com)



Plate 7.3 Product cutting and slicing machine
(Images published with permission of Boskovich Farms, Inc., California, USA.
www.boskovichfarms.com)



Plate 7.4 Continuous product washing flume
(Image published with permission of
Boskovich Farms, Inc., California, USA.
www.boskovichfarms.com)



Plate 7.5 Centrifugal driers

(Image published with permission of Boskovich Farms, Inc., California, USA. www.boskovichfarms.com)



Plate 7.6 Auto scale with form-fill-seal packaging unit

(Image published with permission of Boskovich Farms, Inc., California, USA. www.boskovichfarms.com)



Plate 7.7 Metal detectors

(Image published with permission of Boskovich Farms, Inc., California, USA. www.boskovichfarms.com)

2. Maintenance of equipment

Establishment of a preventive maintenance programme helps to ensure proper functioning of all equipment. Failure of equipment during production may increase the risk of microbial contamination, particularly from *L. monocytogenes*.

Preventive maintenance includes the periodic examination and maintenance of equipment such as valves, gaskets, O-rings, pumps, screens, filters and heat exchanger plates. Appropriate action plans should be developed by small processors in the event of malfunctioning of important equipment, such as refrigeration equipment, disinfectant delivery systems, power systems or alarm systems. The following practices are also recommended:

- ▶ Maintenance and calibration of equipment by appropriately trained personnel. Maintenance personnel who work in the processing or packaging areas should be knowledgeable of, and comply with the hygiene requirements for production staff.
- ▶ Frequent sharpening of knives, if used, including retractable knives, and disinfecting them prior to use. Knives should be replaced if damaged or if they cannot otherwise be maintained in a sanitary condition.
- ▶ Frequently inspecting cutting blades and belts during processing operations for damage, product residue build-up or cleaning needs. Blades should be removed and separately cleaned. Remaining equipment parts must be disassembled (if possible) and cleaned on a regular basis.
- ▶ Installation, calibration and maintenance of temperature measuring or recording devices to ensure their accuracy.
- ▶ Operating of metal detectors in accordance with manufacturers' instructions and checking for proper functioning at least on a daily basis to ensure effective detection of metals and removal of affected products. Procedures should be in place, such as the use of metal detectors during packaging operations, to minimize the possibility of metal entering finished product packages.
- ▶ Calibration of safety control devices that are essential for maintaining the proper level and activity of wash water disinfectant, at a frequency recommended by the manufacturer and documentation of this activity on instrument calibration forms/logs.
- ▶ Examination of air filters for both intake air and compressed air and changing at least as often as the manufacturer specifies, or more frequently if a problem is indicated, such as evidence of filter fouling or perforation.

3. Equipment suppliers

Equipment has been developed over the past decade specifically to meet the needs of the fresh-cut produce industry. Many companies in Europe and the United States sell a wide range of new and second-hand equipment and supply technical services for the maintenance and running of the equipment. A few equipment suppliers are listed below.

Heinzen Manufacturing International (HMI)

Heinzen Manufacturing International
405 Mayock St
Gilroy, CA 95020, USA
Tel +(408)842-7233; E-mail: www.Heinzen.com

Heinzen Manufacturing International (HMI) is a full-service engineering and fabrication company specializing in the design, production and installation of food-processing equipment. HMI draws upon a wide range of depth and experience, from custom-built fruit processing lines to complete heavy construction projects. Heinzen Manufacturing has been satisfying customers for over 25 years. HMI produces a range of products including: *auto scale equipment, bin dumpers, chilling systems, conveyors, cull systems, centrifugal driers, filtering systems, metal detectors, pack-out equipment, platforms, shakers, sizing equipment, slicing and cutting equipment and trimming lines.*

Urschel Laboratories Ltd.

P.O. Box 2200,
2503 Calumet Ave., Valparaiso,
Indiana 46384-2200 USA
Tel +(219)464-4811; Fax +(219)462-3879; E-mail: www.urschel.com

Urschel Laboratories, Inc. is a leader in the designing, manufacturing and selling of precision food-processing equipment. This includes commercial potato chip slicers, cheese shredders, fruit dicers, French fry cutters, meat dicers, peanut butter mills, poultry dicers, lettuce shredders and other types of size reduction equipment. Urschel® food-processing equipment is used by most major food processors in the United States and in over 100 countries worldwide. Urschel updates manufacturing technology by introducing new slicers and dicers, providing sales/service worldwide.

Turatti Srl

Turatti Srl Viale Regina Margherita, 52
30014 Cavarzere Venezia Italia
Tel. +39 0426310731; Fax +39 0426310500; E-mail: www.turatti-na.com (Turatti North America)

Turatti designs and manufactures a wide range of machinery and equipment systems serving the entire food-processing industry. With main offices in Italy, their products are sold worldwide.

(Disclaimer: The mention of these suppliers is for information only as an example; it does not imply endorsement of the companies' products and equipment they supply.)

Chapter VIII

TRACEABILITY OF FRESH-CUT PRODUCTS

1. Traceability in fresh-cut chains

According to the Codex Alimentarius, *traceability* or product tracing is “the ability to follow the movement of a food through specified stages of production, processing and distribution”. This definition encompasses two concepts: tracking, which refers to the ability to determine in real time the exact location and status of produce in the logistics chain; and tracing, which refers to the ability to reconstruct the historical flow of produce based on records maintained through the chain. The objectives of a good traceability system should be to improve supply management and aid tracing of food safety and quality parameters.

The benefits of a well-run traceability programme include:

- ▶ Improved efficiency at all levels within a company thus resulting in revenue generation.
- ▶ The ease with which the source of a safety or quality problem can be isolated and managed.
- ▶ Reduced risk of bad publicity, lawsuits and recalls.
- ▶ Reduced risk of rejection because unsafe products are not shipped and are quarantined thus contributing to the speed with which corrective actions is increased when food safety and quality problems are identified.
- ▶ Information retrieval is facilitated during a product recall or food-borne illness outbreak.

Many large restaurant chains and retailers now expect their suppliers to create traceability systems. These systems are verified through third party audits of their overall food safety system. A traceability programme should record information from the field to the retail display. Stringent legislation, consumer concerns about food safety and growing pressure from retailers have forced food manufacturers to look at every possible means of ensuring traceability and efficiency throughout the supply chain.

2. Record keeping

Minimal farm information to be recorded for a traceability system includes:

- ▶ Plot number or some form of identification for land where the crop is grown.
- ▶ Records of Good Agricultural Practice (GAP):

- pesticide application
- fertilizer application
- irrigation and water testing
- land history
- neighbouring land use.
- ▶ Harvest crew records:
 - records of training
 - reports of illness.
- ▶ Dates of harvest:
 - special conditions during harvest.
- ▶ Farm equipment and trucks used in the production and transport of fresh fruits and vegetables:
 - name of driver
 - vehicle registration number.

Minimal packing house or fresh-cut processing records to be recorded for a traceability system, include:

- ▶ Quality assurance records of the fresh commodity on arrival at the packing house or processing facility.
- ▶ Records on fresh-cut processing staff:
 - records of training
 - records of illness.
- ▶ Good manufacturing practice (GMP) records:
 - records on sanitation
 - records on pest control
 - records on equipment maintenance
 - records of water tests
 - records of temperature during processing.
- ▶ In-process monitoring records of quality assurance.
- ▶ Packaging identification:
 - supplier
 - lot number
 - date of intake.

Distribution information to be recorded for a traceability system includes:

- ▶ Vehicle identification:
 - vehicle type
 - plate number.
- ▶ Container:
 - temperature
 - cleanliness
 - non-conformances.

- ▶ Driver identification:
 - names and contact numbers of drivers.
- ▶ Shipping company:
 - name, address and location of company.

3. Monitoring traceability

In the past, a traceability code would be written or printed on each box and depending on the clarity of information in the code, a company could be contacted to review information associated with it. Only limited information would be contained in a hand-written code, for example the date of harvest or perhaps the lot number.

Bar coding has improved the way product movement is managed. A unique bar code is prepared for products harvested on farm. This bar code stores information on the grower, farm lot number, day harvested and crop harvested. A bar code placed on a bin of fruit after harvest could then be scanned at the packing house at intake. This code stays with the bin until it is repacked into a retail package. If products were stored before repackaging, the warehouse management system would assist in stock rotation based on information received from the bar code. When products are repacked into consumer packages, a new bar code is placed on the product to assist in tracing finished products back to the field in case of an emergency.

The Uniform Code Council (UCC) takes a global leadership role in establishing and promoting multi-industry standards for product identification and related electronic communication. International standards in bar coding include the use of a Global location number or GLN. This is a number that identifies any legal, functional or physical location within a business or organizational entity. The GLN contains 13 digits, all of which must be processed. GLNs can be presented in bar code format and can be physically marked on to trade units in order to identify the parties (buyer or supplier) involved in the transaction.

Some sectors of the food industry have moved on to the new technology of radio frequency identification (RFID) systems. RFID is a technology that makes use of grain-sized computer chips to track items at a distance. Each tiny chip is connected to an antenna that picks up signals beamed at it from a reader device. On picking up a signal, the chip communicates its unique identification number to the reader device, allowing the item to be remotely identified. 'Spy chips' as they are sometimes referred to, can beam back information anywhere from a radius of a few inches to 30 feet (~10 metres) away.

Under the USFDA Recording and Reporting Rule of the Bioterrorism Act, 2002, food companies must provide the USFDA with source data, including immediate previous source (IPS) and immediate subsequent recipient (ISR) for every component of a food item. Many companies have developed software databases and information systems with the ability to store detailed crop history and distribution data. European Union legislation for traceability will drive the industry in the European Union even further to develop adequate information systems.

4. Challenges for the fresh-cut produce industry

Capturing a change in the lot number of produce as it moves on a production line may prove difficult. Furthermore, mixed lots of products in a single package (a fruit salad, for example), complicate traceability, particularly if components of the mix are sourced from different growers. In the event of a crisis, large quantities of products might have to be recalled if the situation is not properly controlled.

Small producers on a limited budget may not be able to afford bar coding systems. However, a detailed number coding system with records to support traceability could provide sufficient information in the event of a crisis.

Chapter IX

LAYOUT AND MAINTENANCE OF A FRESH-CUT PROCESSING FACILITY

1. The fresh-cut processing plant

The type of building in which food products are manufactured and the general level of plant hygiene have a major influence on product quality. This Chapter focuses on basic principles for the design of a small fresh-cut plant. Equipment layout, product flow and food safety are described. Ideally a food manufacturer should have a building constructed specifically for the purpose. Care should be taken to assure compliance with GMP, if an existing building must be modified to accommodate fresh-cut processing operations.

2. Choosing the site of a fresh-cut processing facility

The following issues must be considered when deciding on the location of a fresh-cut processing facility:

- ▶ Distance of the facility from the supply of raw materials;
- ▶ Accessibility of the processing facility;
- ▶ Accessibility to expected markets;
- ▶ Availability of local labour;
- ▶ Environment in which the plant is located – is the building situated in a clean area or is it in the vicinity of an area with much dust, waste or stagnant water?

Fresh fruits and vegetables are bulky and spoil rapidly. It is therefore best to locate the plant close to the area of production in order to reduce transport and handling costs. Excessive handling of fresh produce results in injury, leading to rapid spoilage. In view of the fact that markets for fresh-cut fruits and vegetables would most likely be located in urban areas, the plant should be located in the vicinity of a main road for easy access.

The fresh-cut processing facility should be located on cleared ground, away from sources of insects, rodents or foul odours. It should have a good supply of potable water, and if required, a reliable supply of electricity. A sealed road should be available to provide access for delivery of raw materials and packaging, and for shipping of fresh-cut products. This road should be well connected to the major road network. Good drainage of the site from front to back would be most desirable.

3. Sanitation design of a processing facility for fresh-cut produce

The external and internal design of the processing facility should facilitate cleaning and prevent product contamination. The surroundings of the facility should be planted with grass to serve as an efficient trap for air-borne dust. The internal walls of the building should be plastered or rendered with concrete. The surface finish of the walls should have no cracks or ledges, which could harbour dirt or insects. The lower walls of the interior of the plant should be tiled or painted with water-proof gloss paint to withstand splashing during equipment cleaning. The upper walls should be painted with good quality emulsion paint.

Natural daylight is less costly than electricity. As far as possible, efforts should be made to use natural light in the building. The size of the building and the number of windows would depend on the level of investment available for construction. Store rooms do not need windows, but require ventilation. All windows, vents and fans should be screened in order to prevent the entry of insects, birds and rodents. Buildings should be pest-proofed with no gaps under the doors. The floor should be curved to meet the walls in order to prevent the collection of dirt. Doors in the processing room should be kept closed unless they are fitted with thin metal chains or plastic curtains to prevent the entry of flies.

Operations must be kept sanitary by cleaning up spills as soon as they occur and by washing the plant thoroughly at the end of each day of production. Wire mesh should be placed over drains to prevent the exit or entry of pests. Washing and toilet facilities must be provided for employees, preferably in a separate building. If this is not possible, two closed doors are required between the toilet and the processing area, to prevent insects and odours from entering that area.

Window ledges should be sloped in order to prevent them from collecting dust, dirt or old clothes that may be left there by workers. All windows should be fitted with fly-proof mesh. Attention must be paid to other points through which insects, birds and rodents can enter the processing room or store-room. Gaps between the roof and the walls and gaps in the roof must be properly sealed. Power lines must be fitted with suitable discs at least 25 centimetres in diameter in order to preclude the entry of rats into buildings.

Floors must be designed so that they drain efficiently. One way to facilitate proper drainage is by sloping all floors toward a central drainage channel. The drain should be covered with a removable grating to facilitate cleaning. Drains are a favourite entry point for pests such as rats and cockroaches and thus drain outlets must be fitted with a removable mesh basket or something similar.

All electric power points should be fixed at least 1-1.5 metres high on the walls in order to ensure that they are not affected by washing operations; although expensive, waterproof power points are preferred in wet areas. Alternatively, they may be suspended above the machines they serve. All 3-phase equipment should be installed by a competent electrician. Good lighting should be provided for the working environment and any bulbs used should be protected from breakage with a shatterproof plastic diffuser or sleeve covers.

Good ventilation is essential and large mesh-covered windows, roof vents and ceiling fans may be used. A reliable supply of potable water for cleaning equipment and for washing operations must be ensured. In situations where water supplies are unreliable, strategies must be used to overcome water supply problems. A simple double-chambered high-level water tank can facilitate water purification by treating cloudy water with chlorine and allowing it to settle in one chamber of the tank, while the other chamber is being used.

The USFDA recommends that the processing facility and its structures (such as walls, ceilings, floors, windows, doors, vents and drains) be designed for easy cleaning and maintenance to protect the products from microbial, physical and chemical contamination.

Product contamination and cross-contamination within the plant can be minimized by designing the operation with sound construction materials and by managing the flow of material and people through the plant. Air flow through the plant must also be managed. Good sanitation should be monitored from receipt of products through pre-cooling, fresh-cut processing, packing and storage operations. Buildings, fixtures and equipment should be maintained in a clean condition that will protect fresh-cut produce from potential microbial, chemical and physical contamination.

The following additional recommendations for building design are provided by the USFDA (FDA/CFSAN 2007):

- ▶ All exterior doors and entrances should be closed when not in use, ensuring an adequate seal when exterior doors and entrances are closed.
- ▶ Waste water should be promptly removed from the processing area and collected in a designated area for primary treatment to prevent product and equipment contamination.
- ▶ Overhead pipelines should be avoided as they could be a source of product contamination by overhead condensate. Catch pans may be used for overhead pipelines, but they should be cleaned on a regular basis.
- ▶ Construction materials made out of wood are not recommended for food contact surfaces as they harbour microbes. Wood splinters could also pose a physical hazard as they could contaminate fresh-cut products. Non-wooden construction material like metal or plastic are recommended because they also reduce the potential for microbial contamination.

Figure 9.1 shows the basic areas of a fresh-cut processing plant to allow for the smooth flow of products, minimizing cross-contamination. Figure 9.2 designed by the United Fresh Fruit and Vegetable Association in 2007 shows the recommended design of a medium to large plant for the flow of personnel, in order to keep cross-contamination to a minimum. Produce therefore moves through the facility from input where there can be high levels of contamination to output where contamination levels are lower.

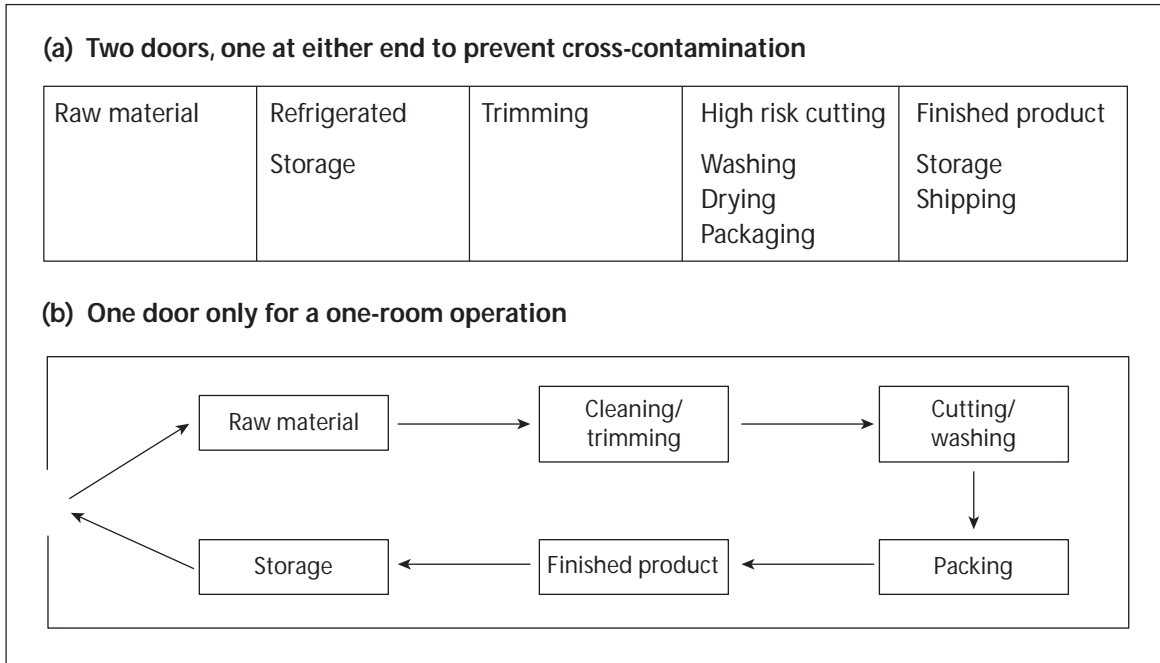


Figure 9.1 Basic design of a small fresh-cut produce processing plant

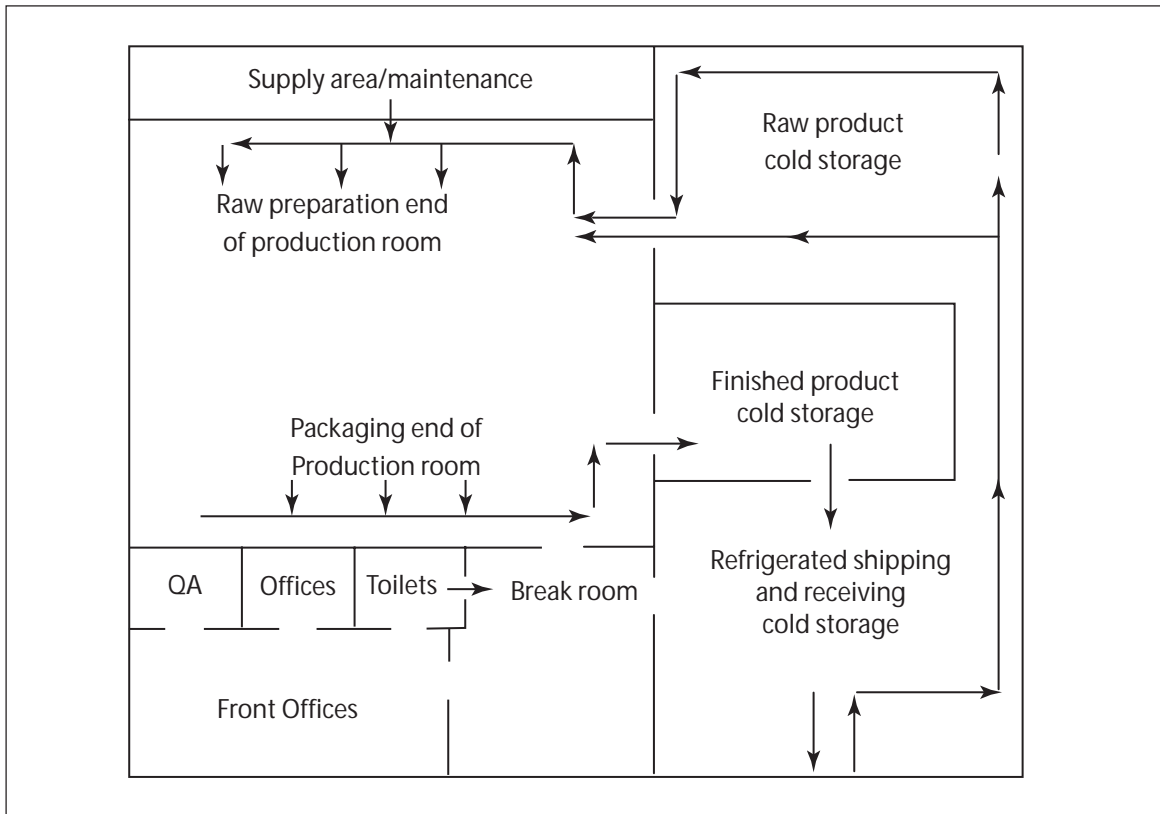


Figure 9.2 An example of product/personnel flow patterns in a fresh-cut processing
(Adapted from United Fresh Fruit and Vegetable Association UFFVA, 2007)

4. Good Manufacturing Practices (GMPs)

GMPs are systems put in place to ensure that food prepared in a plant is sound and free of contamination. GMPs include:

- ▶ Food safety programmes;
- ▶ Management systems;
- ▶ Pest control programmes;
- ▶ Operational methods and personnel practices;
- ▶ Maintenance for food safety;
- ▶ Cleaning practices.

GMPs are monitored and audited by government agencies and private firms on behalf of retail clients. Each agency should have developed rigorous standards based on the main GMP principles. GMPs are a prerequisite to establishing an HACCP programme.

5. Cleaning practices for fresh-cut processing facilities

The overall cleanliness of a food-processing unit, however small, can have a major impact on the quality of finished products. For example, particles of food that are trapped in the corner of a tank or in a pipe, can allow the growth of microorganisms and this can cause major contamination of products during processing on the following day.

Management should develop the following:

- ▶ A master cleaning schedule for daily, weekly and deep cleaning activities.
- ▶ Detailed cleaning methods for each type of equipment and for each area in and around the fresh-cut processing area.
- ▶ Assignment and training of staff in cleaning methods and recording information.

A successful sanitation programme is one in which staff is well trained in cleaning methods and is assigned specific responsibility for each area of the processing facility.

6. Pest control for fresh-cut processing facilities

Pests such as rodents, birds and insects are known to harbour human pathogens. Pests can enter food packing and processing areas through cracks and crevices, thus rendering food susceptible to contamination. A well-planned, preventive pest control programme would help to deter pests from the food handling area.

Management is responsible for:

- ▶ Pest proofing of all buildings that house food – all cracks and crevices must be sealed, windows must be screened and the perimeter of the building must be kept clean and clear

- ▶ Conducting routine inspections for rodents and flying insects, and other pests, with the use of preventive measures like rodent bait, bird traps or mouse traps.

Large processing facilities generally employ pest control companies on contract to visit and conduct routine inspections of the facilities and to prepare a report at each visit. In small operations, one staff member could be trained in pest monitoring and control so as to facilitate the conduct of regular inspections and recording of information. Maintaining clean, sanitary surroundings helps in reducing the risk of pest entry.

Chapter X

EMERGING AND GROWING CONCERNS OF THE FRESH-CUT PRODUCE INDUSTRY

Consumers in developed countries are becoming increasingly concerned about the conditions under which their food is grown and transported. A growing need for ethical food production, traceability as well as preservation of the environment has been voiced by consumer groups to create public awareness.

1. Carbon footprints of fresh-cut produce

The cost of food production is lower in developing countries, where labour costs are a fraction of those in the developed world. Bananas are transported from Central and South America to Europe for consumption on a year-round basis. Other commodities are shipped or air-freighted over thousands of miles to provide food all year round. Developed countries are not subject to the limits of seasonality because fresh produce can be sourced from many areas to meet their needs for year-round supply.

'Food miles' refer to the distance food travels from the point of its production until it reaches the consumer or end-user. The food miles created by transporting commodities over long distances have raised alarm with some consumer groups and environmentalists, who believe that carbon emissions impact the environment (AEA 2005).

Food travels an estimated 30 billion kilometres each year in the United Kingdom. This estimated distance includes travel of imports by boat and air and transport by lorries and cars. The transportation of food is responsible for the United Kingdom adding nearly 19 million tonnes of CO₂ to the atmosphere each year, contributing to a huge 'carbon footprint'. Over 2 million tonnes of this CO₂ is produced simply by cars travelling to and from shops.

One school of thought is that choosing food that is locally produced and seasonal would reduce the distance over which food must travel. Reducing the number of food miles could have a dramatic effect globally on the reduction of CO₂ emissions (Food Action 2005). However, in densely populated urban centres with little or no agriculture, the practice of local consumption would be very difficult to implement.

Figure 10.1 shows an estimate of the food miles from the CO₂ generated by the food industry in the United Kingdom. One issue when calculating these figures was whether the CO₂ resulting from transport during import/export is attributed to the importing or exporting country. The graph includes transport within the United Kingdom, but *not* overseas transport during import/export.

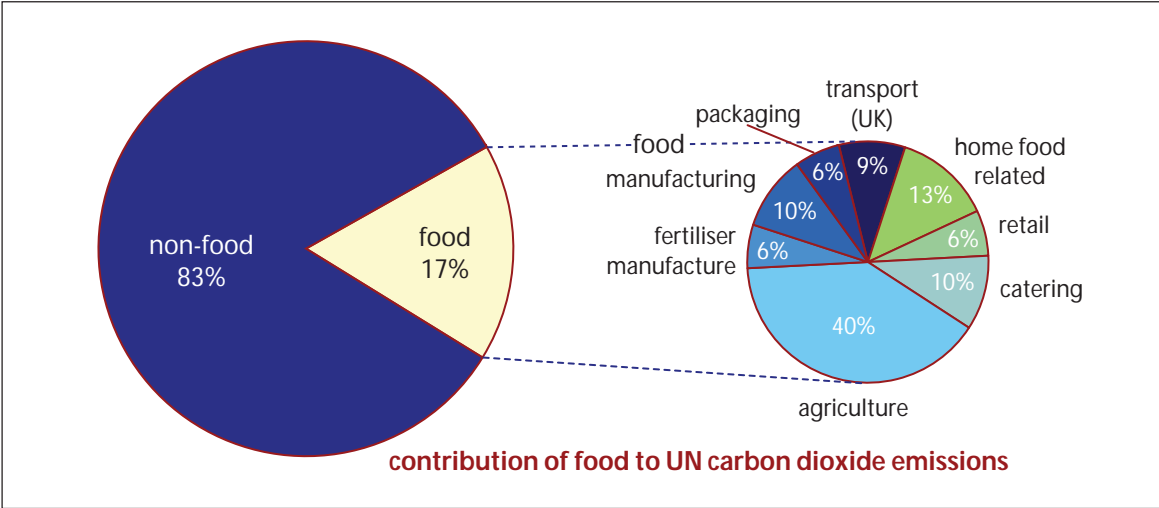


Figure 10.1 Food contributions to CO₂ emissions in the United Kingdom (AEA 2005)

2. Waste management in fresh-cut processing

Another significant concern in developed countries is that of waste management. Many programmes are being developed to recycle and sort the enormous volumes of waste generated by consumers. The 'Green Movement', as it is called in some countries, educates customers on separating waste – glass bottles, paper, plastic, organic matter – so that waste may be recycled or broken down for use as manure. Cardboard or paper packaging is preferred over plastic packaging because it may be recycled and the board reused to form packaging. In fact plastic is equally recyclable, if not more so.

In addition there is the waste material produced from the processing of fresh-cut produce itself, the unwanted material that is peeled, trimmed and cut from the fresh fruits and vegetables during their preparation into fresh-cut products. Fresh-cut products must also be disposed of after reaching their use-by dates without being bought or consumed in time. All of these wastes can amount to a huge cost for a country. In the United Kingdom alone, the volume of this wasted food amounts to about 6.7 million tonnes, which is disposed of in landfills each year. This food includes packaged foods that have never been opened. A new study says that reducing the waste of food in the country could prevent 18 million tonnes of CO₂-equivalents from being emitted each year – the same as taking one in five cars off British roads.

This food waste might be converted into biofertilizer and renewable energy instead of sending it to landfills where it creates methane, a powerful greenhouse gas.

3. Factors that influence future growth of the tropical fresh-cut produce industry

Developed countries are leading the way in innovation in the fresh-cut produce industry. Government regulations, as well as large retail groups, are demanding higher standards of sanitary design for processing plants and packaged food. Automation and custom-made equipment are rapidly replacing hand-cutting operations.

Foreign bodies in products are being removed using automated detection systems. Chlorine, traditionally used as a disinfectant in wash water, is being replaced by a host of other chemical and non-chemical treatments as the by-products of chlorine are thought to be cancer-forming. Retailers demand a longer shelf-life and research is progressing in MAP and in ideal storage conditions to prolong shelf-life.

Future growth and development of the tropical fresh-cut industry will hinge upon:

- ▶ Principles and practice of fresh produce traceability;
- ▶ Microbiological issues related to fresh produce;
- ▶ Developments in the packaging of fresh-cut produce;
- ▶ Advances in sulphite-replacement technologies for fresh-cut produce;
- ▶ Safe and effective biocides for washing and decontamination; and
- ▶ Recovering value by reducing waste in the fresh-cut produce industry.

All of these concerns in the modern export market pose challenges which must be met by developing countries.

Chapter XI

PROCESSING AND PACKAGING OF TROPICAL FRESH-CUT FRUITS AND VEGETABLES IN THAILAND

1. Fresh-cut produce

Fresh-cut produce has been marketed by street vendors in Thailand for many years. Fresh-cut products are widely sold in wet markets and are increasingly sold in supermarkets across Thailand. A range of fresh-cut vegetables, including leafy vegetables (basil, unchoi, kale etc.), chilli, lemon grass, galangal, asparagus, baby corn, peanut sprouts and ready-to-cook vegetables is also exported.

The fresh produce sections of large Thai supermarkets contain a myriad of fresh and fresh-cut fruits and vegetables. A survey conducted by Sa-nguanpuag *et al.* (2007) reported that fresh-cut vegetables command a larger market share than fresh-cut fruits in regular and upscale supermarkets. This survey also determined that the price of fresh-cut produce was higher than that of intact fresh produce. Growth in the Thai fresh-cut industry has been largely due to increasing incomes and an increasing number of working couples and families who have little time to prepare their meals from scratch.



Plate 11.1 Fresh-cut fruits on display in a high-end Thai supermarket
(Courtesy of E. Esguerra, UPLB)



Plate 11.2 Fresh-cut products sold in the fresh market in Bangkok
(Courtesy of A. Hicks)

2. Processing of fresh-cut fruits

Fresh-cut fruits are produced at the small vendor level, at the supermarket level and by small processors in Thailand. Steps in the processes vary in accordance with the target market (Figure 11.1). Small vendors who target the mass market, generally retain produce on ice, while cutting on demand. Supermarkets on the other hand, which target the higher end consumer who is increasingly safety and quality conscious, cut and package fresh-cut fruits under hygienic conditions on a daily basis and display them on ice or under chilled conditions. Small processors who also target supermarkets and the food service sector, often include an anti-browning treatment as a processing step, given the lag time between production and marketing, and given the expected longer shelf-life of their products.

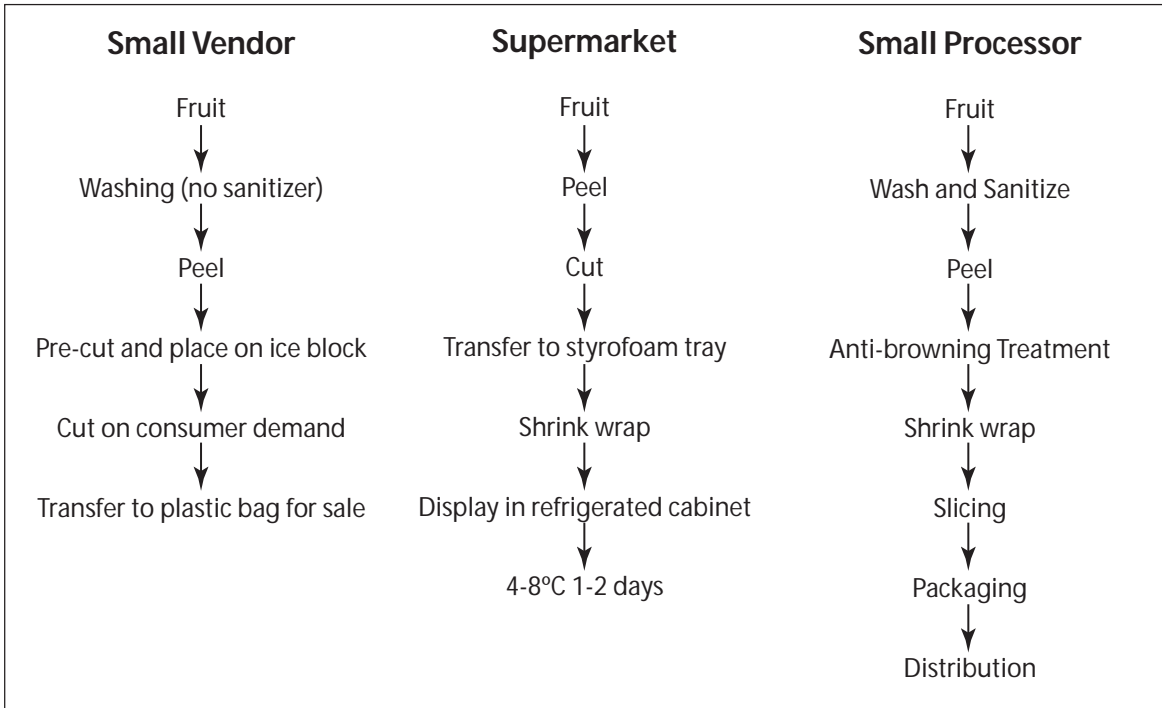


Figure 11.1 Steps in the production of fresh-cut fruits in Thailand for different target markets

3. Processing of selected fresh-cut fruits for the export market

Fresh-cut papaya (Carica papaya)

Harvesting

Papaya should be harvested when approximately 75-80 percent of the skin of the fruit turns yellow. The fruit should be cut off the tree using scissors or a sharp knife. It is recommended that the stem be cut closer to the tree trunk in order to prevent damage to the fruit. The stem of the harvested fruit must subsequently be cut to approximately 1 inch. Fruits must be carefully packed in baskets and transported to the processing facility.

Grading and sorting

Papaya must be sorted for uniformity of size and color, firmness, freedom from defects such as skin abrasions pitting, insect injury and freedom from decay.

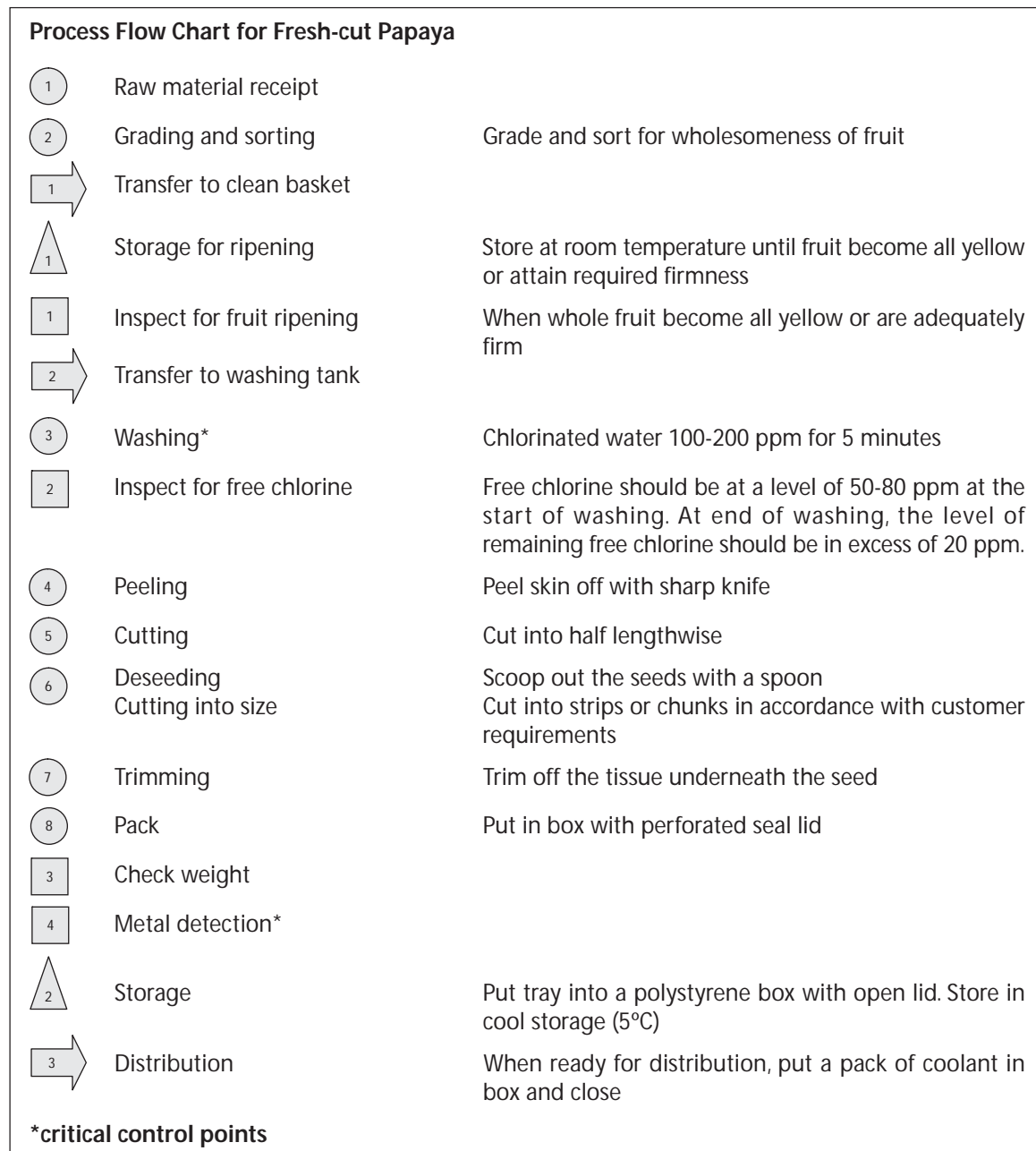


Figure 11.2 Process flow chart for the production of fresh-cut papaya for export

Fresh-cut pineapple (Ananas comosus L.)

Harvesting

Pineapples should be harvested in the early morning or late in the evening to protect fruit from the sun and to reduce the heat load on harvesting. Pineapples are harvested by snapping fruit from the stalk using a downward motion. The fruits should be placed in baskets upside down on the crown and while in the field, left under shade. The stems and the crowns should be trimmed.

Pineapples should be transported as soon as possible after harvest to the packinghouse and should be pre-cooled to remove field heat. This can be done either by submerging in water, or by air cooling. Should water be used, it should be chlorinated and frequently replaced. Fruits with a high level of flesh translucency can be separated at this stage as they sink on immersion in water.

Grading and sorting

Pineapples must be sorted for the required color stage of ripening and for uniformity of ripening. They must be fresh and clean in appearance, free of wounds from harvesting or handling, including scratches, punctures or bruises.

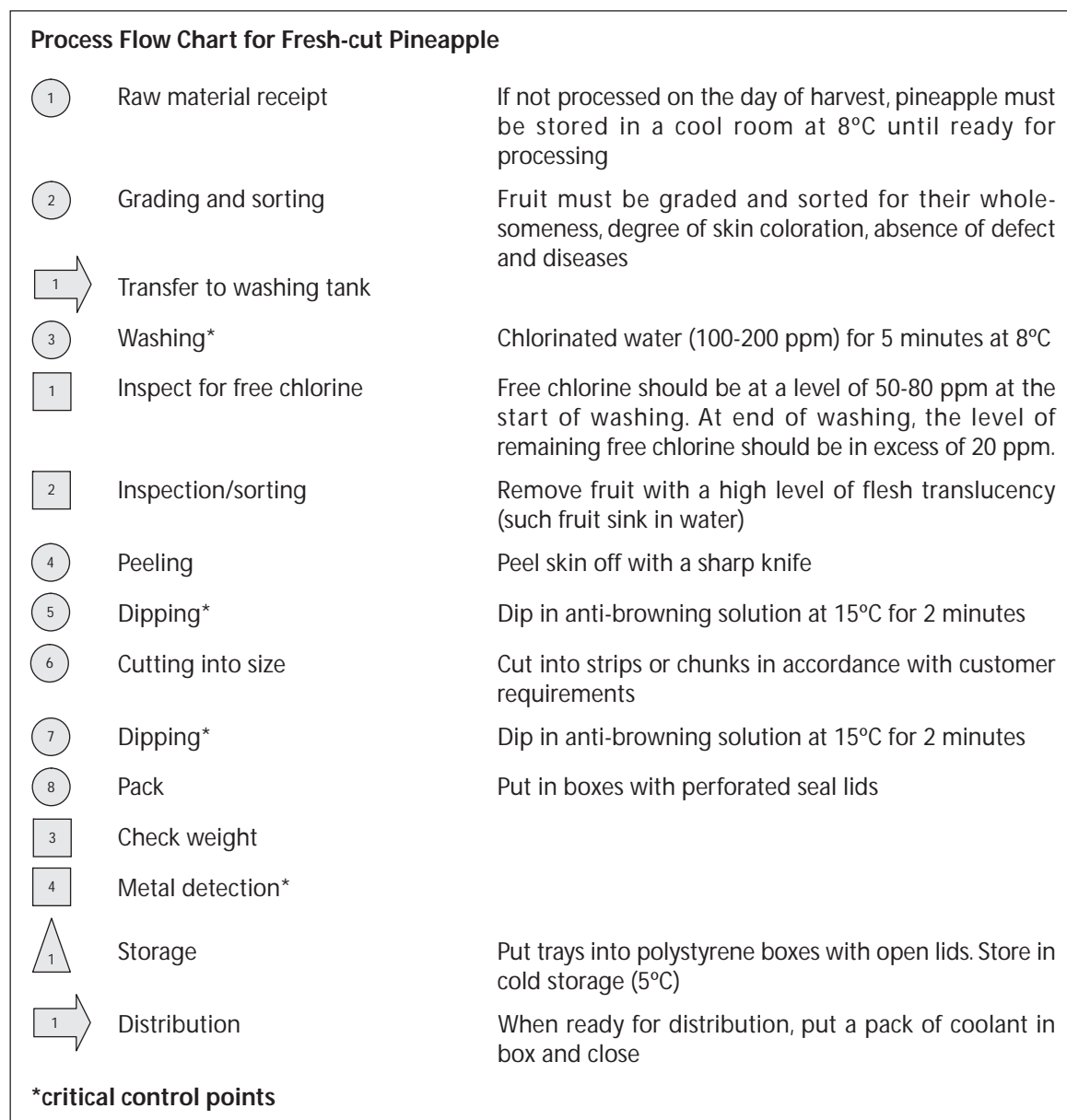


Figure 11.3 Process flow chart for the production of fresh-cut pineapple for export

Fresh-cut pummelo (Citrus maxima or citrus grandis)

Harvesting

Pummelos should be harvested between 6.5 and 7.5 months after full bloom. Fruit harvested later than 7.5 months after full bloom are generally sweeter. Determination of the harvesting date is dependent on the sugar/acid ratio required by the customer and on the cultivar.

Pummelos should be harvested by cutting the stem of the fruit with scissors and dropping the fruit into a cloth bag. The harvested fruit is then transferred to a basket and kept in the shade, following which is transported to the processing facility and stored in a cool room at 10°C and 85% RH.

Grading and sorting

Fruits damaged by pests must be separated out.

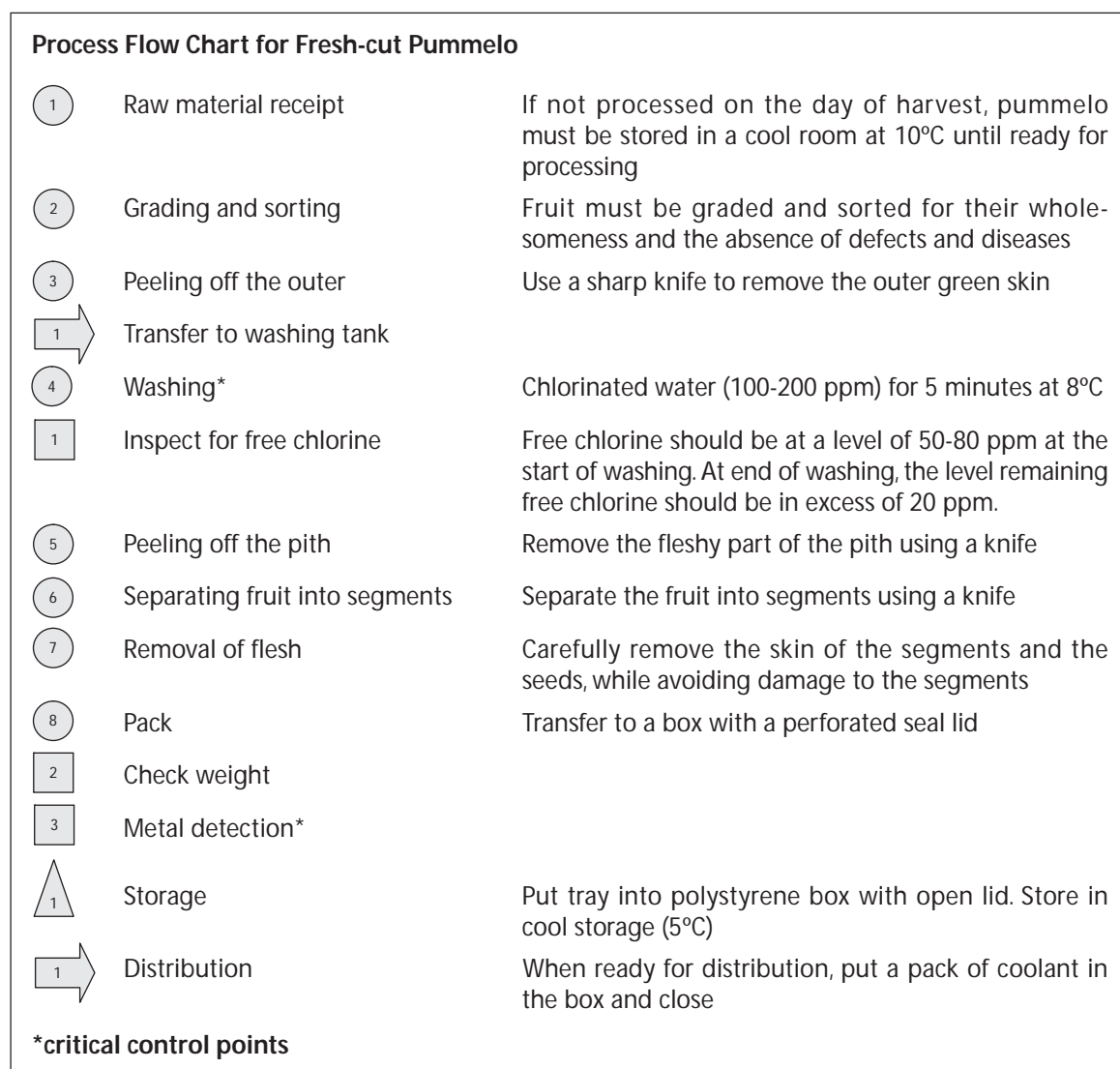


Figure 11.4 Process flow chart for the production of fresh-cut pummelo for export

Fresh-cut Watermelon (*Citrullus lanatus* Thunb.)

Harvesting

Watermelons should be harvested at 25-30 days after full bloom or when the ground spot (the portion of the melon resting on the soil) changes from pale white to a creamy yellow color. Experienced farmers or fruit sellers use the knocking of sound fruit as an indicator of the maturity index of watermelon fruits. Immature fruit give off a metallic ringing sound while mature fruit give a dull or hollow sound.

Fruit are harvested by cutting them off the vine using scissors. They are transferred to a basket and left under shade.

Grading and sorting

Watermelons must be sorted for maturity and for damage caused by bruising and cracking.

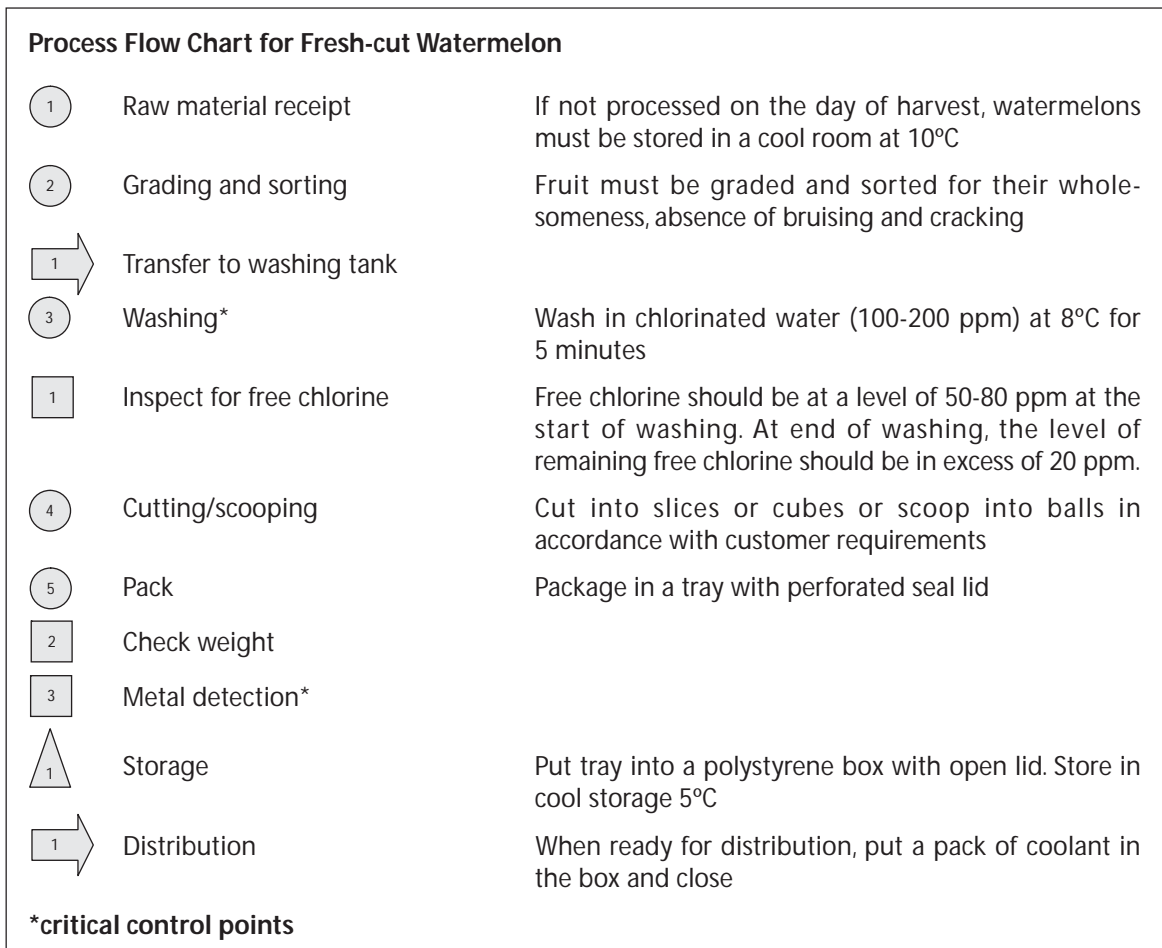


Figure 11.5 Process flow chart for the production of fresh-cut watermelons for export

4. Processing of fresh-cut non-leafy vegetables

Fresh-cut vegetables are sold in wet markets and supermarkets and are packaged for export. Steps in the processes vary in accordance with the target market (Figure 11.6). Small vendors generally trim the produce prior to cutting and selling in the wet market under ambient conditions. Supermarkets on the other hand, generally wash the produce prior to trimming, cutting and packaging, under hygienic conditions. Vegetables destined for export are subjected to more stringent processing conditions, wherein they are trimmed, cleaned, cut, washed, sanitized, dried and packaged.

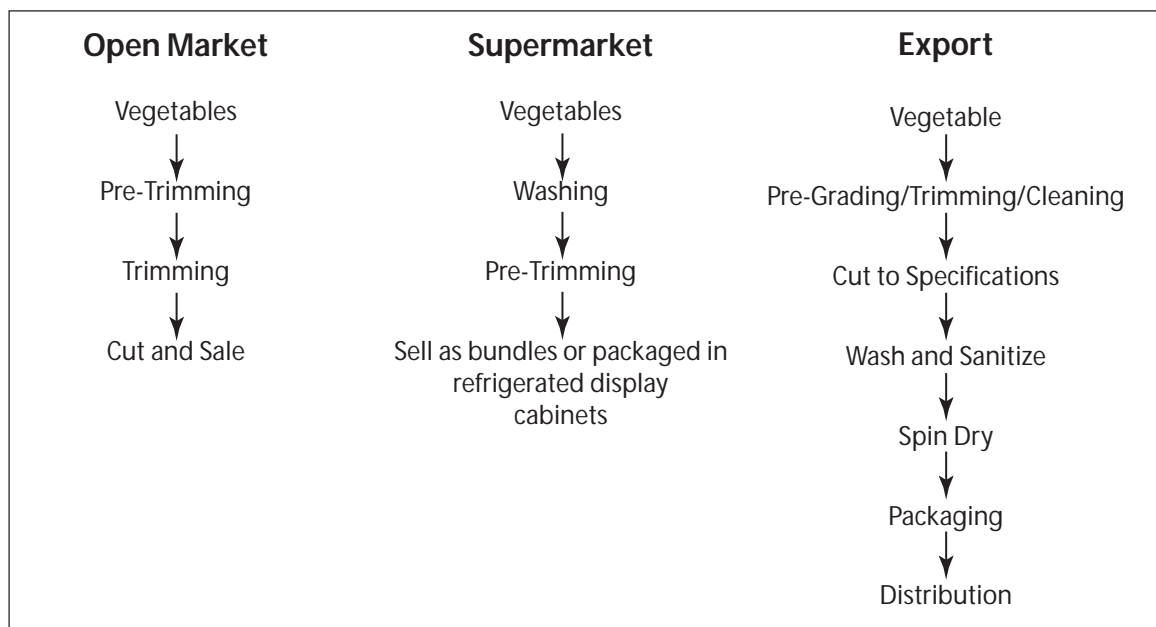


Figure 11.6 Steps in the production of fresh-cut fruits in Thailand for different target markets

5. Processing of selected non-leafy vegetables for export from Thailand

Fresh-cut Asparagus (Asparagus officinalis L.)

Harvesting

Asparagus must be harvested according to length, diameter, and condition of tips and in accordance with customer specifications. In order to slow respiration, asparagus must be harvested either during the early morning or evening, when temperatures are cool.

Grading and sorting

Asparagus is graded into classes and also sorted for wholesomeness, freedom from damage caused by pests, freedom from any visible foreign matter, freedom from bruising, fresh in appearance and fresh-smelling.

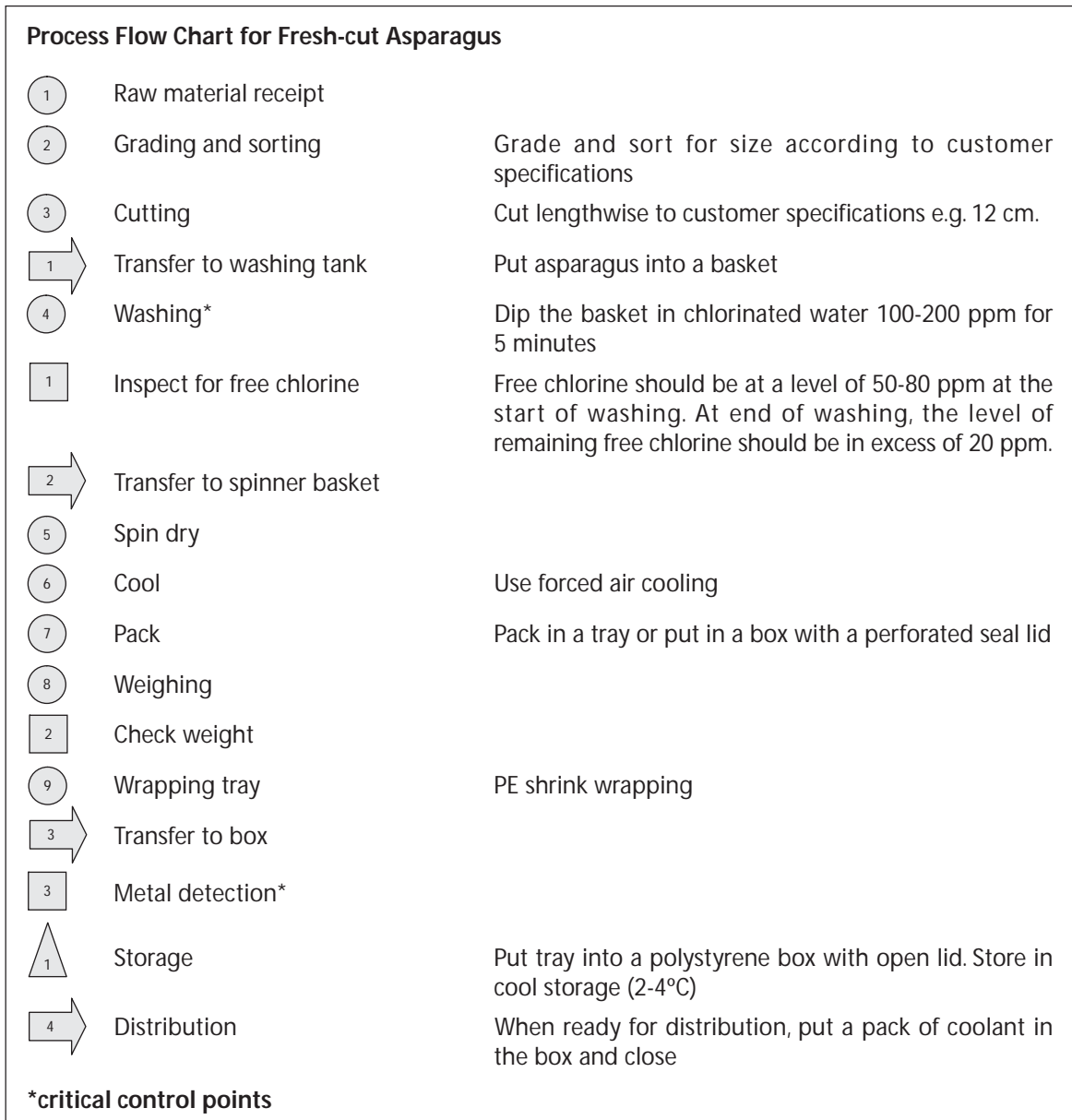


Figure 11.7 Process flow chart for the production of fresh-cut asparagus for export

Baby corn (Zea mays L.)

Harvesting

The harvest index for baby corn is indicated in various ways. Observation of the emergence of silk length could be one practical index. Baby corn must be hand-harvested 2 to 3 days after silking or when the silk emerges 1-2 centimetres from the top end of cobs, or when the plant is 45-50 days old. The top cob must be harvested first, followed by harvesting of the second cob after 1-2 days. Baby corn must be harvested over 7-10 days to avoid overgrowth of the cob and changes which lead to a fibrous texture.

Cobs must be properly cooled using forced-air cooling immediately after harvest. When possible, harvesting should be carried out in the morning, when the moisture content is highest and product and ambient temperatures are low.

De-husking

Baby corn cobs must be hand husked and the silk must be removed. In order to facilitate de-husking, a thin sharp knife should be used to open and peel off the husk. Care should be taken not to break or damage the cob in the process.

Grading and sorting

Baby corn must be sorted for wholesomeness, freedom from damage caused by pests, freedom from any visible foreign matter and bruising, fresh in appearance, and practically free of silk. The cut on the base of the cobs should be clean.

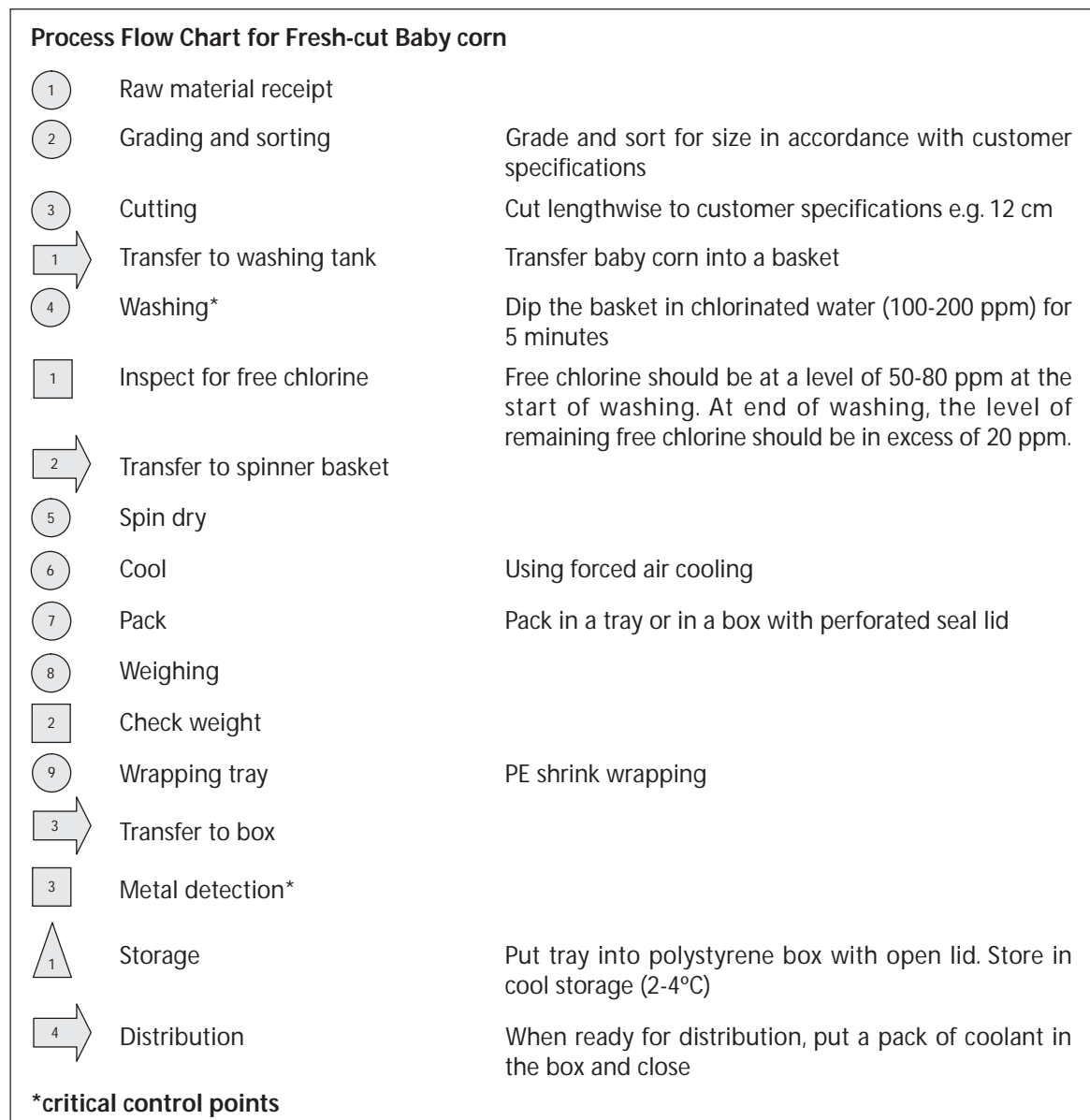


Figure 11.8 Process flow chart for the production of fresh-cut baby corn for export

6. Fresh-cut mixed vegetables: baby pak choi, sweet pepper, asparagus and baby corn

Pak choi (Brassica chinensis)

Harvesting

Pak choi is harvested by hand at the age of 25-30 days in order to obtain young leaves. The head must be carefully cut at the base and deep in the soil, in order to leave the shoot system intact and undamaged and to reduce water loss. Harvesting should start from midmorning to midday. Following harvest, external and damaged leaves must be removed and care must be taken to avoid bruising during all operations. Pak choi must be transferred to a clean plastic basket or box with plastic over wrap and stored in a cool room prior to processing

Grading and Sorting

Pak choi heads are graded according to their size and the quality of their leaves.

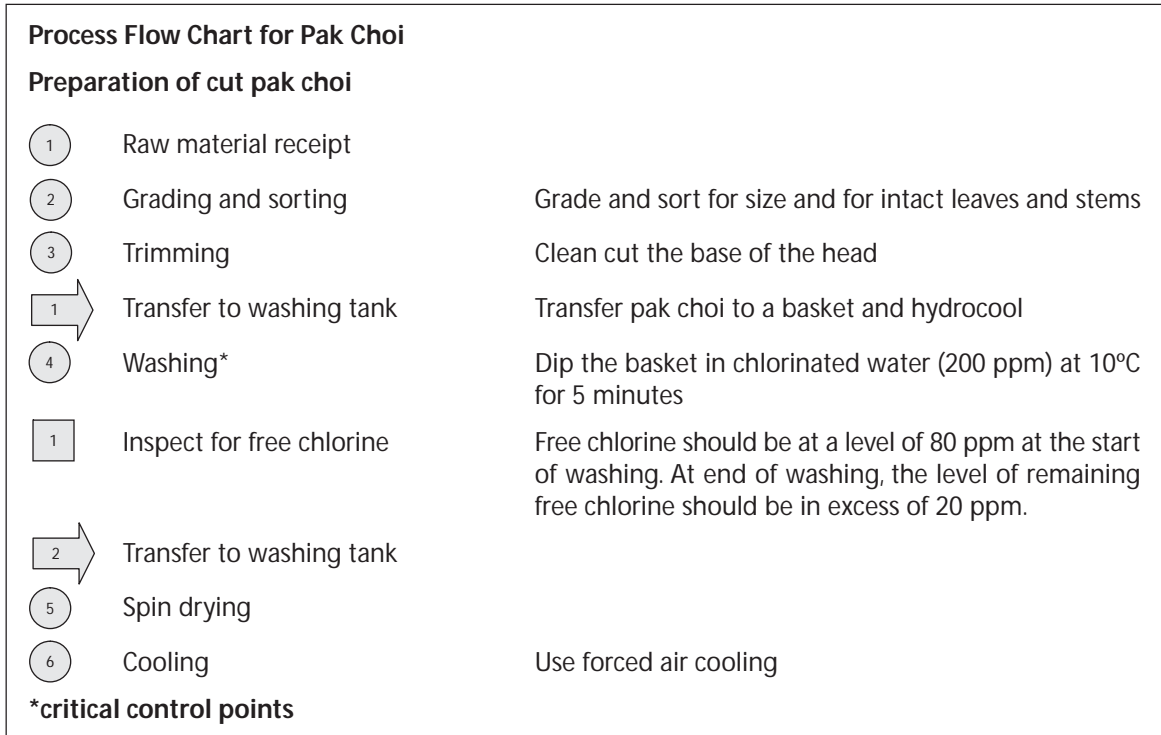


Figure 11.9 Process flow chart for the production of fresh-cut pak choi for export

Sweet Pepper (Capsicum annuum L.)

Harvesting

Green peppers must be harvested when they are shiny and firm, usually at full color stage (light green color) for greenhouse-grown peppers and at the mature green stage (dark green color) for field grown peppers. Red peppers are harvested from the plant at a later stage when the fruit turns red.

Sweet pepper must be hand harvested using a thin, sharp knife to cut the fruit from the stem and to avoid bruising. Peppers should be cooled soon after harvest using either forced air cooling or hydrocooling. In situations where hydrocooling is applied, peppers should be immediately blow dried with air. Peppers are packed in a box and are transferred to a processing plant.

Grading and sorting

Sweet peppers are sorted for firmness, freshness in appearance and freedom from blemishes.

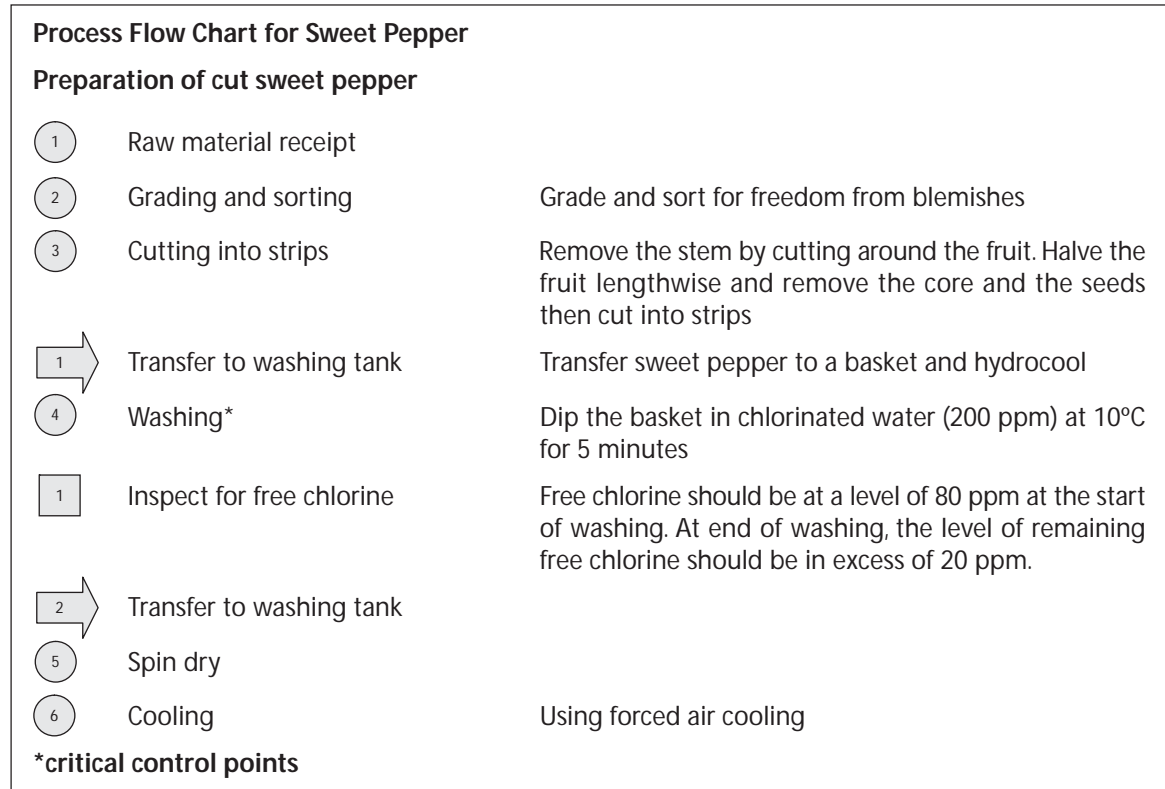


Figure 11.10 Process flow chart for the production of fresh-cut sweet pepper for export

Fresh-cut Ready-To-Cook mixed vegetables: baby pak choi, sweet pepper, asparagus and baby corn

Ready-to-cook mixed fresh vegetables: (1) whole head of pak choi cut lengthwise between 8-10 cm, (2) green and red sweet pepper cut into strips (3 x 5 cm), (3) asparagus approximately 6 cm in length and (4) baby corn cobs with the husk, silk and stalk removed, between 5-7 cm and in width and 1-1.2 cm.

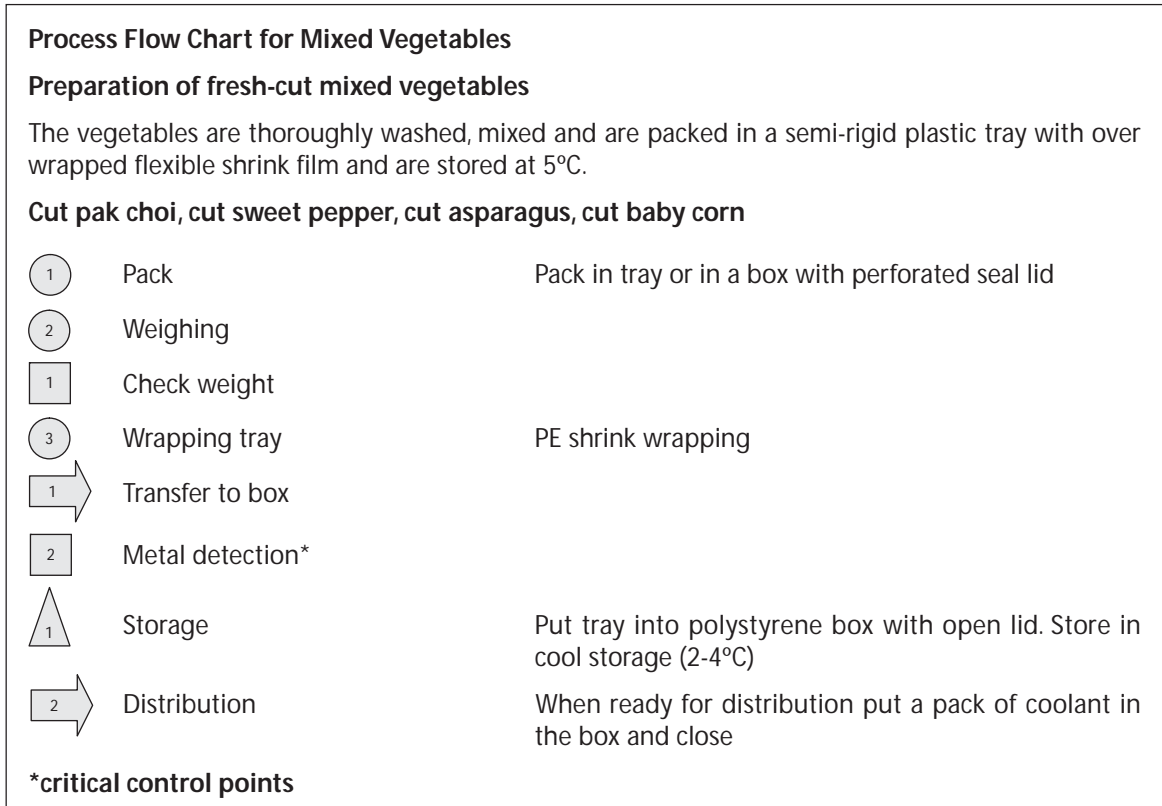


Figure 11.11 Process flow chart for the production of fresh-cut mixed vegetables for export

7. Packaging of fresh-cut produce

Packaging is critical in the handling and marketing of fresh-cut products. Plates 11.3 and 11.4 show a number of packaging formats used for the marketing of fresh-cut produce in Thailand. Salad mixes are generally packaged in printed flexible packs (Plate 11.5) or in clam shell packs (Plate 11.6). Foam trays overwrapped with polyvinylchloride film (Plate 11.3) are the most widely-used packaging system for fresh-cut fruits intended for direct consumption and for use as ready-to-cook ingredients.



**Plate 11.3 Pummelo in overwrapped foam trays on sale
in the open market in Bangkok**
(Courtesy of A. Hicks)



**Plate 11.4 Pineapple in different packaging formats
on the open market in Bangkok**
(Courtesy of A. Hicks)



**Plate 11.5 Bagged salads sold in higher-end supermarkets
in Bangkok**

(Courtesy of V. Chonhenchob, Kasetsart University)



**Plate 11.6 Salads marketed in a clam shell pack
in high-end Thai supermarkets**

(Courtesy of V. Chonhenchob, Kasetsart University)

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