FOOD AND VEGETABLES TECHNOLOGY

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CHAPTER 1

THE INDIAN FRUITS AND VEGETABLES INDUSTRY

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After China, India is the world's second-largest producer of fruits and vegetables. Because of the country's varied geography and temperature, fruits and vegetables are available throughout the year. India produced 107.10 million metric tons of fruits and 204.61 million metric tonnes on vegetables between 2021 and 2022. In 2021–2022, there were 7.09 million hectares of land under cultivation for fruits, compared to 11.28 million hectares for vegetables. Along with plantain, papaya, mango, and guava, India also tops the globe in the output of ginger and okra.Indian fruits and vegetables are now more often produced and exported. India exported fresh produce totaling US$1.527.60 million during 2021 and 2022, consisting of US$ 750.7 million in fruits and US$ 767.01 million in vegetables. The UAE, Bangladesh, Afghanistan, Saudi Arabia, Sri Lanka, and Nepal are India's primary export destinations. Even though India only accounts for roughly 1% of the world market, its horticultural goods are getting more and more well-liked thanks to improvements in cold chain infrastructures, research, modern post-harvest technology, helpful governmental laws, and quality control methods

Production of Fruits and Vegetables in India

The Food and Agriculture Organization (FAO) of the United Nations ranked India as the second-largest grower of fruits and vegetables worldwide. The largest fruit-producing states in India are New Delhi, Telangana, Uttar Pradesh, Uttar Pradesh, Tamil Nadu, Karnataka, and Gujarat. India has a sizable food sector. Uttar Pradesh, Madhya, Bengal, Patna, Rajasthan, Odisha, and Maharashtra are the top vegetable-producing states. With a 3.0% CAGR, fruit output in India climbed from 97.97 lakh mt in 2018–19 to 107.10 million tonnes in 2021–22. Additionally, through this whole time, the market's output of vegetables increased by 3.8% Growth to 204.61 million tonnes.

Fruits and Vegetable Exports from India

Due to its extensive industrial base, India has enormous export potential. Over the two-year period 2021–22, it exported fresh product worth Rs. 11,412.50 crore (US$ 1,527.60 million), of which fruits and vegetables were worth Rs. 5,593 crore (US$ 750.7 million) and Rs. 5,745.54 crore (US$ 767.01 million), respectively. A total of Rs. 12,858.66 crore (US$ 1,724.88 million) worth of processed fruits and vegetables (including pulses) were exported during this time, of which Rs. 8,308.04 crore (US$ 1,114.19 million) and Rs. 4,550.62 crore (US$ 610.69 million) were processed vegetables, such as pulses. Grapes, pomegranates, mangoes, bananas, and oranges are the main fruits exported, while onions, white beans, potatoes, tomatoes, and green chilies are the main vegetables exported.

Compared to the same period last year, processed fruits and vegetables showed a significant gain of 51% between April and July 2022, while fresh fruits and vegetables only witnessed an increase of 3.79%, according to preliminary statistics from the General Directorate of Trade Intelligence and Statistics. Exports of fresh produce reached a total of US$498 million during this time period, and US$517 million over the same months of this fiscal year. Exports of vegetables and processed fruits increased significantly during the initial four months of this fiscal year, reaching US$ 441 million to US$ 665 million.

Government Initiatives to Promote Exports of Fruits and Vegetables

The industries and agriculture sectors both heavily rely on fruits and vegetables. The government has proposed many measures to enhance chances in the fruits fresh vegetable business and promote exports due to their relevance for the nation's economic development. Below is a list of a few of these reforms: In the industry of food processing100% Foreign Direct Investment (FDI) permitted for the food processing sector:

The government had authorized 100% FDI via the automated method. The goal was to reduce the regulatory barriers impeding invest in equipment into the sector and the nation while also making the FDI policy increasingly favorable to investors.

Agriculture Export Policy (AEP):

In 2018, the Indian government unveiled its agriculture export policy, emphasizing output that is export-oriented, export promotion, increased farmer awareness, and alignment with government interventions.

Mobile apps for farmers are valued by the AEP. Giving farmers and Farmer-Product Organizations (FPOs) a share in the sale of their goods has advanced significantly throughout the implementation of AEP. Direct linking of FPOs/farmers with both the exports market has increased farmers' earnings and resulted in better agricultural practices as a result of the requirement to service international markets.

Direct Involvement of Farmers in Exports:

Farmer Connect Portal:

A platform for FPOs, Farmer Producer Companies (FPCs), and cooperatives to interact with exporters has been established on the website of the Agricultural and Processed Food Stuffs Export Development Authority (APEDA). Currently, the platform has 2,360 FPOs/FPCs and methods to identify exporters registered.

Systems for traceability

To ensure the quality all exports and position India as a reliable supplier of high-quality commodities, traceability down to the farm level is crucial. To promote simple business flow and guarantee system transparency, several digital platforms for tracing have been developed.

Addressing Transport and Logistics Issues

The Indian Railways has presented the Kisan Train system, under which rail lines are run with myriad commodities (perishables, agricultural products, and seeds), consignors, and consignees, in order to assist farmers and farmers transport their agricultural goods from rural areas to significant towns and cities. To date, 157 Kisan Commuter trains have been conducted by the Indian Railways on 18 routes to transport perishable items including fruits, vegetables, and other consumables. The Operation Veggies (TOP to TOTAL) initiative of the Ministry of Food Manufacturing Industries (MoFPI) offers a 50% subsidy on the Kisan Rail transport of fruits and vegetables.Fresh-cut fruit and vegetables, also known as minimally processed or lightly processed products, are any fresh fruit or vegetable that has been physically modified from its original form (by peeling, trimming, washing, and cutting) to produce a 100% edible product that is then bagged or prepackaged and stored in refrigerated storage (IFPA, 2005). Fresh-cut produce encompasses all types of fresh commodities and their combinations in various cuts and packaging. Things like bagged. Salads, baby carrots, stir-fry vegetable combinations, and fresh-cut apples, pineapple, or melon are just a few choices. Fresh-cut commodity manufacturing and consumption is not new. According to the International Fresh-Cut Produce Association (IFPA), fresh-cut items have been offered to consumers in retail supermarkets since the 1930s. The fresh-cut sector, on the other hand, was first formed to provide hotels, restaurants, catering services, and other organisations. Fresh-cut produce has a number of advantages for the food service industry and restaurants, including a reduction in the need for manpower for food preparation, a reduction in the need for special waste-handling systems, and the ability to deliver specific types of fresh-cut products in a short period of time. Yet, it was not until the last two decades that fresh-cut fruit and vegetables became popular.

Improvements in Fresh-Cut Fruits and Vegetables As fresh fruit and vegetable consumption has increased, so has the popularity and penetration of processing goods in the produce industry. The fresh-cut fruit and vegetable sector is continually expanding, owing to customers' desire for nutritious, quick meals as well as their interest in the role of food in increasing human well-being. Indeed, the World Health Organization (WHO), Food and Agricultural Organization (FAO), United States Department of Agriculture (USDA), and European Food Safety Authority (EFSA) have all advocated increasing fruit and vegetable consumption to reduce the risk of cardiovascular disease and cancer (Allende et al., 2006). Consumption of fresh whole fruit grew from 282.1 to 284.6 lb/year per capita in nations such as the United States during the last decade of the twentieth century (USDA, 2003), most likely as a result of greater public knowledge about the importance of good eating habits.

Fresh-cut items, on the other hand, are a highly practical method to offer consumers with ready-to-eat delicacies. Fresh fruit and vegetables that have been washed, cut into bite-size pieces, and packaged allow consumers to eat healthy on the go while saving time on food preparation.For example, making fresh-cut fruits available in vending machines in schools and workplaces would be an excellent strategy to improve the nutritional quality of snacks and convenience foods at a time when obesity and nutrition-related illnesses affect large populations. Apart from ease, there are additional factors that contribute to the popularity of freshcut food, such as the absence of waste material. Peeling and coring fruit generates waste. By using fresh-cut produce, however, 100% is consumable, and there is a significant reduction in effort necessary for home produce preparation and trash disposal.

According to an IFPA poll, 76% of studied families purchase fresh-cut produce at least once a month, and 70% purchase fresh-cut fruit every few months (IFPA, 2003). Fresh-cut fruits and vegetables are preferred by around 30% of customers over their unprocessed counterparts. Moreover, Sonti et al. (2003) found that women are more likely than males to buy fresh-cut fruit, and that as income level rises, so does the likelihood of consuming fresh-cut fruits.

Since the early 1980s, fresh-cut fruits and vegetables, packed salads, locally grown goods, and exotic food, as well as hundreds of new types and processed products, have been introduced or expanded. Supermarket produce sections now stock over 400 goods, up from 150 in the mid-1970s and 250 in the late 1980s. In addition, the number of ethnic, gourmet, and natural food stores emphasising fresh-cut produce is growing. Table 1.1 includes some fresh-cut food that is currently accessible in supermarkets. Packaged salads remain the most popular fresh-cut product due to its convenience and constant quality. Packaged salads now account for around 7% of total produce section sales. In fact, in nations such as the United States, packaged salads have surpassed bottled water as the second-fastest-selling item in grocery shops (Bhagwat, 2006). According to Garrett (2002), another section of the fresh produce market that had considerable development in the 1990s was organically grown fruits and vegetables, which included both whole commodities and fresh-cut items.

Global Market Tendencies

People are eating more fresh-cut fruit and vegetables these days as they try to replace bad snack items with healthier fruit and vegetable products. This tendency has prompted the fresh-cut business to boost its investment in R&D to solve concerns like as raw product supply, packaging technology, processing equipment, and refrigeration. Gained popularity in the fast food industry:

1. Prepared Fruits, Leafy Salads, and Mixed-Tray Salads
2. pineapple chunks Salad with radicchio Salad with a ribbon of lettuce Cucumber + lettuce
3. Selection of sliced melon Rocket Salad with peppers
4. Salad with tropical fruits Salad with baby leaves Salad with prawns and noodles
5. Salad with fruits Salad with spinach, watercress, and rocket Niçoise tuna
6. Sliced pineapple Salad mix Salad with pasta and cheese
7. Salad with fresh fruits Salad on the patio Salad with white and red cabbage
8. pieces of mango Salad à la carte Salad with sweet peppers
9. Grapes, kiwis, and pineapple Salad Caesar Asian edamame the soya bean
10. Apple and grapes Salad with Italian leaves Salad with Greek dressing
11. Pomegranates Salad with herb dressing Salad of crunchy lettuce and cucumber
12. Salad with mixed fruits Salad with crispy leaves Salad with poto, peas, and beans

E. Garner (2008) is the source. Fresh-cut convenience is a European trend. Freshconex, Berlin, Germany, hosted a conference. Based on a 52-week period ending in December 2007.Fresh-Cut Fruits and Vegetables Advances Processing fresh-cut vegetables is now offered at retail. This paved the path for continued business growth, including recent additions of fresh-cut fruits at quick-service restaurants and retail establishments.

Fresh-cut fruit production and commercialization have increased fast in recent years, while fresh-cut vegetables, particularly salad, dominate the production of minimally processed foods. According to Mayen and Marshall (2005), the burgeoning fresh-cut fruit industry will likely overtake salad sales in the future because fresh-cut fruits are more appealing to young consumers and ageing baby boomers, and are more likely to be consumed as snack goods in general. Moreover, fresh-cut fruits have better margins than packaged salads from retail, resulting in sufficient display space in shops.

Trends in the United States

Fresh-cut produce has recently boomed all over the world, particularly in several American nations; nonetheless, the majority of production and consumption is focused in North America, with the United States leading the way.Fresh-cut produce originally appeared in retail marketplaces in the United States in the 1940s, but it was second-class, deformed produce, quality was uncertain, and shelf life was short. Fast food restaurants used shredded fresh-cut lettuce and chopped onions in the mid-1970s. Salad bars first appeared in the mid-1980s, when fresh-cut vegetables began to replace canned goods. In fact, the food service industry has seen the most growth in fresh-cut fruits and vegetables in the United States.

Fast food restaurants like McDonald's and Burger King were thriving in the United States in the 1980s, thus fresh-cut materials used in their salad bars and ready-to-eat salads, particularly fresh-cut lettuce, were in high demand. McDonald's used 80 million pounds of salad greens (including spring mix), 100 million pounds of leaf lettuce and iceberg lettuce on sandwiches, 30 million pounds of tomatoes, 54 million pounds of apples for apple dippers and fruit and walnut salad, and 6.5 million pounds of grapes in the United States alone in 2006 (McDonald's, 2006). Fresh-cut produce is now one of the fastest growing food categories in US supermarkets, with packed salads being the most popular item offered (Figure 1.1). Moreover, micro carrots, available in a variety of sizes, are the most popular Stock Keeping Unit (SKU) washed, peeled, and packaged—in the United States (USDA, 2003).

Fresh-cut fruit and vegetable sales in the North American food service and retail industry have increased to around $15 billion per year, accounting for nearly 15% of total produce sales. According to the United Fresh Produce Association (2007), fresh-cut salads account for the majority of retail fresh-cut produce sales in the United States, accounting for $2.7 billion in sales every year. Yet, the fast food industry is growing demand for packaged fresh-cut fruits by giving healthier menu options. According to Scott (2008), fresh-cut fruit sales in the United States grew for all products, with increases ranging from 7% to 54%. Melons were the fastest growing sector. This tendency is projected to continue for the foreseeable future. A number of consumer market research assessments anticipate that demand for fresh-cut fruit items will continue to rise, with food service organisations and schools leading the way (Figure 1.1).

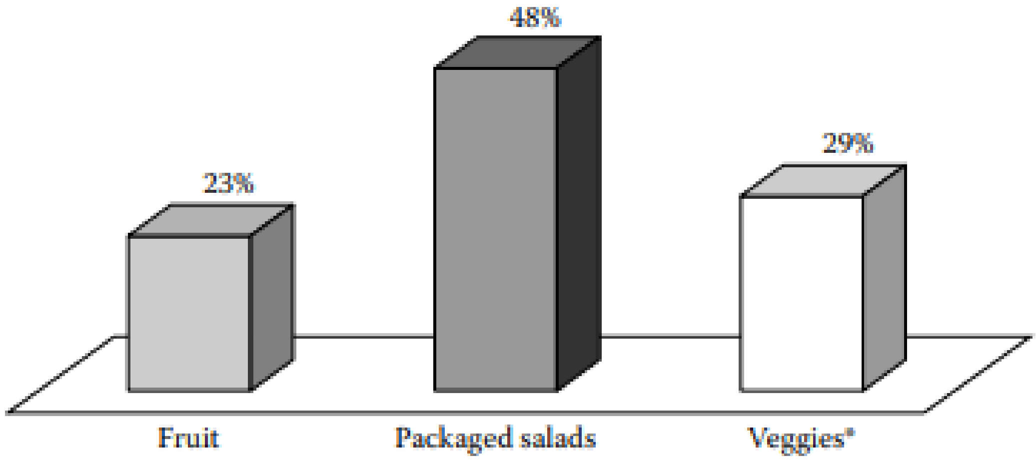

Figure 1.1 represent the Fresh-cut produce sales via supermarket channels

Customers who frequent lunch programmers (Anonymous, 2000; Gorny, 2003). According to a 2008 Perishables Group survey, mixed fruits and vegetables, watermelon, pineapple, carrots, and mushrooms had the highest sales and profits.

Fresh-cut item volume in the United States

According to Information Resources, Inc., Ready Pac is the most prominent firm in fresh-cut fruit sales in the United States, with a market share of 23%, followed by private-label store brands (31%), Del Monte (13%), Country Fresh (7%), Club Fresh (3%), and Fresh Express (1%). (2003). Fresh-cut fruit from several of these enterprises includes pineapple, melons, grapes, citrus, apples, and kiwi. In the case of fresh-cut veggies, freshexpress and Dole had 42% and 48% of retail packaged salad sales, respectively, in 2005, followed by Ready Pac (8%) and other firms (4%)? (PMA, 2006). Numerous lettuce varieties, including radicchio, arugula, and red oak, have grown in popularity in recent years as a result of their inclusion in fresh-cut salad mixes and on luxury restaurant menus.Salad mixes accounted for 37% of the salad market in 2005, behind iceberg lettuce (13%), romaine lettuce (11%), garden salads (8%), salad kits (6%), organic salad blends (4%), premium garden blends (83%), shredded lettuce (3%), spinach (3%), and miscellaneous (12%). (PMA, 2006).

European Trends

Florette Group brought fresh-cut goods to Europe in the early 1980s in France. It was Europe's first fresh-cut vegetable production plant, and it later began other activities to export to other nations such as the United Kingdom, Italy, and Swiss. Fresh-cut products have been adapted to each country according to consumer preferences, production, distribution, and legislation.In Spain, for example, Vega Mayor created fresh-cut goods, which have been available on the Spanish and Portuguese markets since 1989. Vega Mayor was bought by the Florette Group twenty years later and is now the Spanish market leader in fresh-cut vegetables. At the moment, the primary manufacturers.

Vega Mayor, Verdifresh, Kernel, Tallo Verde, Sosegol, and Primaflor are Spanish market tradersBut, in recent years, various food companies have begun to promote their innovative fresh-cut items. For example, Vitacress, the second largest corporation in the English market following their debut and success in Portugal, is now expanding into the Spanish market through Vitacress Iberia. Cofrusa, for example, provides fresher items like as salads, prepared veggies, and, more recently, individual pieces of fresh-cut fruits.The fresh-cut fruit and vegetable markets in Europe differ by country.In some, shops provide a diverse selection, whilst in others, ready-to-eat food is nearly unheard of.Many European nations are experiencing growth in the fresh-cut market, with the United Kingdom, France, and Italy leading the way. Ready-to-eat mixed salad packs have been one of the UK food industry's biggest triumphs over the previous decade.

The United Kingdom leads the industry, supplying 120,000 tones of fresh-cut salads in 2004, worth €700 million ($840 million in the United States); France follows with 77,000 tonnes of fresh-cut and grilled/steamed veggies. In 2004, sales in Italy topped 42,000 tonnes of output, equating to €375 million ($450 million US) (Nicola et al., 2006). Germany, the Netherlands, Spain, and the United Kingdom now have the highest growth rates in the fresh-cut fruits and vegetables market (Figure 1.4). (Garner, 2008). According to the most recent Afhorla (Spanish Association of Washed and Ready-to-Use Fruit and Vegetables) figures, Spanish sales totaled 14,675 tonnes between January and April 2006, an increase of 18.5% over the same months in 2005. Fresh-cut items account for 5% of total fruit and vegetable consumption in Spain. According to certain estimations, this market might expand by more than 25% every year.

The typical European consumes up to 3 kilograms of fresh-cut items each year, however there are significant disparities across Europe. For example, in the United Kingdom, the rate is 12 kg per capita per year; in France, the rate is half that of its neighbor, at 6 kg per capita; and in Italy, the rate is roughly 4 kg. Belgium, the Netherlands, and Germany are other nations where fresh-cut foods are firmly established, but significantly less so than the previously named. In each of the nations In the 1990s and 1980s, fresh-cut goods were introduced in Korea and Japan, respectively. Originally, the food service industry for school meals and restaurants was the primary user of fresh-cut goods in both nations, but in recent years, consumption has spread to retail markets (Kim and Jung, 2006). Since the late 1990s, the market for fresh-cut items in China has been rising, with more Western fast food firms entering and thriving in the Chinese market.

Korea is one of Asia's fastest-growing economies, having a diverse range of retail items. There were 102 firms manufacturing fresh cut vegetables in 2006. Before the late 1990s, supermarkets did not sell fresh-cut fruits.In South Korea. The fresh-cut fruits business, on the other hand, has lately seen double-digit growth rates, reaching an estimated $50 million in 2006. (Kim, 2007). Despite this growth, fresh-cut vegetables continue to dominate fresh-cut item production, with salad prepared from iceberg lettuce being the most popular fresh-cut produce, accounting for 48.7% of total fresh-cut veggies.According to the Korean Fresh-cut Produce Association (KFPA), the fresh-cut produce industry in Korea reached $1.1 billion in 2006, up from $530 million in 2003. Fresh-cut produce sales in Japan increased from over $1 billion in 1999 to $2.6 billion in 2005, accounting for around 10% of total fresh produce sales.

The food service industry in Japan, which distributes produce to restaurants, fast-food outlets, and school meals, accounts for around 66% of the overall fresh-cut market.

Fresh-cut produce sales in the retail sector, including supermarkets and convenience shops, amount $0.9 billion, accounting for 34% of the overall market. According to a 1999 research conducted by the Association of Minimally Processed Fruits and Vegetables (AMPFV), there are 161 firms in Japan that produce fresh-cut goods.

The most popular fresh-cut vegetables and fruits in Japan include iceberg lettuce, onion, cabbage, Japanese radish, edible burdock, potato, Chinese cabbage, pumpkin, sweet pepper, cucumber, carrot, watermelon, pineapple, and melon. Cut lettuce, cabbage mixes, coleslaw, bean salad, tomato salad, onion salad, corn salad, Caesar salad, and a broad range of specialized mixes are available in this nation from producers such as Dole. According to the AMPFV (2004), the total input of vegetables to fresh-cut production in Japan in 2002 was 92,672 tones.Although there is no precise statistics on the size of China's fresh-cut fruits and vegetables industry, China will become the largest consumer of these items in the future. For example, a new fresh-cut facility was created in Beijing three years ago.

Closing Comments

Fresh-cut fruits and vegetables are commodities with a fast increasing food business sector that includes both retail and food service locations. At the time, technology is the primary component that has encouraged and sustained fresh-cut sales. Permanent developments, on the other hand, are required to generate fresh growth in this area. Usage of novel packaging technologies that might increase product quality and shelf life, new fruit mixes with greater diversity, flavour inclusion, or the use of steamer bags for vegetables are just a few factors that could boost freshcut product markets. There is a diverse range of veggies available worldwide that might be employed to diversify and expand market product possibilities. Yet, in many nations, preparation and preservation processes must be improved in order to keep the product secure and of good quality long enough to enable the distribution of fresh-cut commodities practical and realistic.

The Types of Law

The introduction of fresh-cut fruits and vegetables (FcFV) to the market as a new type of product expanded the human food supply chain. It introduced certain new problems for producers, but it did not create a new form of legislation. FcFV are governed by the laws of the nation in where they are farmed, harvested, processed, transported, and sold to consumers by caterers and merchants.When foods are traded abroad, the applicable food law doubles. The food laws of all participating nations, as well as international food law, are therefore relevant, if only to harmonise the laws of the various legal systems. The Codex Alimentarius Commission (CAC) is an international intergovernmental body that sets food standards, recommendations, and best practises. Although an international body can only provide recommendations to member nations, the Codex Alimentarius, a compendium of CAC food legislation, has significant power.

Many instruments are used in national and international food laws, including binding legislation and regulations, as well as several voluntary instruments, such as good practises, particularly

Good Agricultural Practices (GAPs) and Good Manufacturing Practices (GMPs), for the successive stages in the food production chain, with other good practises for the remaining stages.

GHP follows the product from start to finish in the production chain.

Hazard Analysis and Critical Control Point (HACCP) systems are equally relevant across the manufacturing chain. Governments issue guidance materials to clarify their regulations; occasionally they rely on voluntary rules developed by food corporations. Several of these voluntary codes have been authorised by government authorities. Letters from public law authorities warn food company operators of the required standards of hygiene, as well as the regulatory powers that might be employed if the industry fails to meet the expectations that are also legal obligations.In summary, there is a wide range of binding and nonbinding law. Although the terms binding law and nonbinding law appear to be a tautology and an inherent contradiction, both forms of law exist. Nonbinding legal devices play an essential role in food law.

There is no clear framework of binding laws, as is normally seen in legislation for food safety, more particular legislation for food hygiene, even more complex rules for fresh produce, and ultimately detailed legislation for fresh-cut fruits and vegetables. It is compounded by the habit of combining binding legislation with nonbinding legislation. Mixing occurs on two levels: legally binding instruments are coupled with voluntary instruments that can be employed as an alternative under particular legal conditions.

On a deeper level, legally binding documents codify the key aspects of a voluntary instrument, such as a GHP. Hence, enforcing these enforceable regulations is an alternative to voluntary good practises. As a result, there is a complex body of legislation that is both soft and hard, voluntary and binding, national and international, intergovernmental and supranational, governmental and private. This chapter presents a sampling of all of these many types of applicable law. It is typical yet far from complete.

Product FcFV are the ultimate result of a long food manufacturing cycle. The final preparation of this food has been transferred from consumers and caterers to a new set of producers who rely on new production methods for ready-to-eat food as well as transportation, distribution, and wholesale logistics to get the FcFV to the retailers and caterers where consumers will buy them in time.

This sort of ready-to-eat food needs not just additional stages in the manufacturing process, but also additional food hygiene procedures. FcFV preparation reduces their inherent resistance to desiccation and contamination.It enhances the contact surfaces between the product and the oxygen in the atmosphere, frees moisture, and provides a plethora of unwelcome organisms with abundant sustenance and optimal life circumstances.

It also prohibits the use of industrial techniques that may erase this contamination, such as freezing or heating to fatal temperatures, as well as sweetening, acidifying, and various antimicrobial and other defences.FcFV production necessitates more control over fruits and vegetables, particularly in the basic production stage, when many possible sources of fresh-cut contamination adhere quickly to the raw material and are difficult to remove.The second big challenge is the phase of the manufacturing chain after the FcFV are made: means to keep them fresh throughout shipment must be devised.

CHAPTER 2

BINDING AND NONBINDING LAW ON FRESH-CUT FRUITS AND VEGETABLES

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FcFV have been involved in food hygiene law in a variety of ways and to varying degrees. The European Commission's legislation on microbiological contamination is an example of binding law. The European Commission has established food safety guidelines for Salmonella in precut fruits and vegetables, as well as *Listeria monocytogenes* in three ready-to-eat items. ‡ A food that does not meet a food safety requirement is removed from the market as well as prohibited from export and import.

It also implies that food service providers must implement a testing programme and perform research to ensure that their goods meet the standards throughout their shelf life.Process hygiene requirements for Escherichia coli have been established in respect to precut ready-to-eat fruits and vegetables.Process hygiene standards must be satisfied by food company operators in the supply, handling, and processing of raw materials and commodities under their control. Failing to fulfil the food safety requirements entails the need to destroy the produce if no other use is conceivable. Failure to achieve the process hygiene requirements necessitates the improvement of the processing or raw material has also garnered nonbinding legislation.

The CAC added voluntary guidelines to the "Code of Hygienic Practice for Fresh Fruits and Vegetables" in the "Annex for Ready-to-Eat Fresh Pre-cut Fruits and Vegetables."must depend on the force of reason and proven success to convince others that a particular excellent practise is a worthwhile instrument for certain purposes.Numerous groups advocate for these best practises. When an international body, such as the CAC, goes beyond mere advocacy and engages in extensive discussions to establish suggested practises, something is contributed to the excellent practise that existed prior to the CAC's nonbinding instrument. For example, scores of government leaders have participated to talks regarding the text's proper formulation. This process includes several discussions in member states during which stakeholders and other interested people and groups are requested to give ideas in order to decide the views that the national representative will adopt.

Reworking a nonbinding best practise into a nonbinding Codex document appears to have no legal significance. When nations participate in CAC decision making, they affect the legal status of the Codex Alimentarius guidelines and good practises. This is strengthened by clear comments in their own laws that they will contribute to the development of international food law and will take this law into account when developing their own legislation. The European

Commission, for example, joined the CAC in 2003 and references to the Codex in various places in its comprehensive collection of food rules.

Good Practices of Many Kinds

Many types of companies develop best practises for operations in the food production chain. Some of these practises are made for certain phases of the food production chain, such as when a GAP is followed by a GMP, and other practises for packing and transportation may be made in accordance with the CAC suggested worldwide Codes of Practice.

The Codex Alimentarius General Food Hygiene Principles

In eleven parts, the General Principles of Food Hygiene cover all areas of food hygiene. Environmental hygiene and public health demand that dangerous environmental contaminants do not enter food at unacceptable amounts. Fresh-Cut Fruits and Vegetables Advances Food processing may take place only where such contaminants do not exist or where adjustments can be made to prevent contamination.The sanitary manufacturing of food necessitates that basic production procedures do not contaminate the food. Producers must test their processes to determine the most probable actions or conditions where contamination can occur and take measures to prevent or minimise contamination to acceptable levels. For this task, the HACCP system is suggested. Producers must control contaminations from air, soil, water, feedstuffs, fertilisers (including natural fertilisers), pesticides, veterinary drugs, or any other agent used in primary production; control plant and animal health so that it does not endanger human health through food consumption; and protect food sources from faecal and other contamination.

The standards for handling, storage, and transportation as part of primary production require sifting collected material to reject sections that are inappropriate for human consumption. The rejected waste must be disposed of in a sanitary manner, and the food must be safeguarded against pests, chemical, physical, and microbiological contamination.

Organization: After the main step, Design and Facilities is concerned with the infrastructure, location, and buildings where food is processed. These facilities must be equipped to conduct excellent food hygiene.

Some areas place a premium on personnel and personal cleanliness. In the basic manufacturing phase, infrastructure such as an appropriate supply of potable water, drainage, and waste disposal systems must be available in any facility or location where food is handled. Personnel hygiene necessitates that the establishment's management offer the necessary facilities for hygienically washing and drying hands, toilets, and changing rooms.Personal hygiene as part of a set of laws governing the repercussions of disease and injury, personal cleanliness, and conduct. Those who are unwell or are carriers of an illness that can be spread through food must be kept from contaminating it. Codex Alimentarius Hygiene Practice for Fresh Produce and Vegetables

The equipment and facilities must be simple to clean and maintained in a systematic manner using cleaning techniques and methods. Pests must be kept at bay and vigorously controlled when they do appear.Trash must be controlled in order to avoid direct contaminationAnnexes to the Code of Hygienic Practice for Fresh Fruits and Vegetables that are commodity-specific The

Codex Committee on Food Hygiene (CCFH) issued a broad call for scientific opinion on the microbial dangers of fresh food.

The following criteria were set by a Food and Agricultural Organization (FAO)/World Health Organization (WHO) Expert Conference to rank the commodities of concern in terms of microbial dangers associated with fresh produce:

The commodities of concern were prioritised into three groups, with leafy greens being the highest priority, level 1. Leafy greens are grown and exported in large quantities, have been linked to multiple outbreaks involving large numbers of illnesses in at least three different parts of the world, and are grown and processed in a variety of and complex ways, ranging from an in packing to precut and bagged product.

The Codex Committee on Food Hygiene's work priorities mirror the ranking.It has created a draught Annex to the Code of Hygienic Practice for Fresh Fruits and Vegetables on fresh leafy vegetables, including leafy herbs.The Annex to the Codex on Ready-to-Eat Fresh Precut Fruits and Vegetables

The regulation on FcFV is devoid of a universally agreed statutory definition of the concepts of fresh-cut product and fresh produce. Without a definition or rules for FcFV, each jurisdiction may have its own definition or rules for fresh-cut produce.Fresh-cut fruits and vegetables and fresh fruits and vegetables are phrases used by the CAC, the curator of the international common consensual fund of core food law principles. In addition to the prescriptions for all foods, it establishes unique guidelines for each category. Yet, it does so without defining the traits that distinguish these items as separate categories with their own set of rules. Legislators frequently establish many auxiliary notions while leaving the principal topic unclear. This is a legal method based on the implicit premise that the collection of rules created for an undefined topic constitutes its legal definition in a broader sense.

1. The Annex covers the extra precautions and production methods for FcFV.
2. As raw materials arrive at the manufacturing site, they must be examined.
3. Animal and plant waste, metal, and other foreign matter must be eliminated.

The water used for final rinses must be drinkable, especially if the items will not be cleansed again before eating. Contamination must be avoided during cutting, slicing, shredding, and similar activities, and sliced food must be cleaned to remove some of the cellular fluids produced during the cutting process.This reduces the amount of nutrients available for microbiological development. Wash water must be replenished on a regular basis to minimise organic material accumulation and cross-contamination. Antimicrobial agents may be utilised in accordance with GHPs.These agents' levels must be monitored and managed. The use of antimicrobial agents must guarantee that chemical residues do not exceed the Codex values. To reduce microbial development, precut fresh fruits and vegetables must be stored at low temperatures at all phases, from cutting to distribution. Records must be kept to give information about the product and the manufacturing process. To support recalls and foodborne disease investigations, these data must be preserved for considerably longer than the product's shelf life.The training sessions must cover packaging systems for fresh precut fruits and vegetables, as well as contamination and microbiological growth threats. The significance of temperature management and GMPs cannot be overstated. The Codex writings have been incorporated into a variety of guidelines, procedures, programmes, standards, and regulations. Because the circumstances for microbial contamination are primarily defined by primary production and packing, a continuous set of procedures from primary production through manufacturing, and then to packaging and transport, is especially crucial for fresh and fresh-cut fruits and vegetables.Codex Recommendations for Appropriate Hygiene Standards in Ready-to-Eat Foods to Control *Listeria monocytogenes*the CAC has developed guidelines for using the General Principles of Food Hygiene to manage *Listeria monocytogenes* in Ready-to-Eat Foods.

These recommendations supplement the CAC RCP 1969 General Principles of Food Hygiene. They are required because *L. monocytogenes* has established a permanent presence in manufacturing and consumer facilities. The prevalence of *L. monocytogenes* in ready-to-eat food processing companies is induced by the following factors:

Because *L. monocytogenes* can exist in biofilms and persist in harbourage sites for long periods of time, processing equipment should be designed, constructed, and maintained to avoid cracks, crevices, rough welds, hollow tubes and supports, close fitting metal-to-metal or metal-to-plastic surfaces, worn seals and gaskets, and other areas that cannot be reached during normal cleaning and disinfection of food contact surfaces and adjacent areas.

Temperature and time control

The risk assessments on *L. monocytogenes* in ready-to-eat foods conducted by the US FDA/FSIS and FAO/WHO indicated the enormous effect of storage temperature on the risk of listeriosis associated with ready-to-eat foods that enable *L. monocytogenes* development. As a result, the time/temperature combination employed for storage must be controlled. The temperature of the product should not exceed 6°C (ideally 2°C-4°C).

The Codex Committee on Food Hygiene is working on microbiological criteria for *Listeria monocytogenes* in ready-to-eat foods.The FAO and WHO advise governments and food industry participants to pay closer attention to the hazards presented by foodborne viruses.Fresh vegetables is one of the primary avenues for viral entry into high-risk commodities. Contaminated water used for irrigation, pesticide application, or wash water; the use of human waste as fertiliser; and manual handling during harvest and postharvest are all causes of viral infection in fresh food. The proportional importance of each is unknown. GAPs, GHPs, GMPs, and irrigation water quality requirements must handle this.

Law of Binding

Human rights, treaties, customary law, legislation, regulation, taxes, and administrative and judicial judgements can all be binding as public law. It is enforceable as private law in contracts, corporations, and real estate.It is not required to establish a separate branch of legislation for each stage of the food production chain. Current legislation, ranging from the most fundamental, such as contract and industrial property law, through general food law and more specific food law for fresh fruits and vegetables, might be enough (FFV).

Food Regulations

Horizontal food legislation includes restrictions that apply to all foods. This sort of regulation includes essential standards for food safety and cleanliness.

Vertical food legislation is designed to offer detailed guidelines for specific situations that are not covered by horizontal legislation. The broadest of all general food law laws establishes the duties of food industry owners by mandating that only safe food be brought to market.

Article 17 ensures that these regulations have a broad reach by establishing the responsibility of food company operators to ensure that their goods fulfil the criteria of food law. The concept "food business operator" defines the category of people who bear primary responsibility: Any venture, whether for profit or not, public or private, carrying out any of the activities associated to any stage of food production, processing, and distribution is characterised as a "food business."

The declaration that food is not placed on the market if it is dangerous is only effective when supported by other elements of the legislation.The Commission lacks the authority to rely on criminal law as a backup. Instead, it must rely on the requirement of member states to provide the regulations for measures and punishments applicable to violations of food law. After the first paragraph on the responsibility of food company operators, the second paragraph of Article 17 GFL continues with the member states' enforcement of food law.

They must maintain a system of official controls and other suitable actions, as well as establish the rules for measures and punishments applicable to violations of food law. "The sanctions and measures must be effective, reasonable, and dissuasive."

The United States also has legislation that states that food must be fit for human consumption: "A food shall be deemed adulterated (a) if it contains poisonous, insanitary, or deleterious ingredients, if it has been prepared, packed, or held under insanitary conditions whereby it may have become contaminated with filth, or whereby it may have been rendered injurious to health. The federal government can enforce this obligation using criminal law.

This requires three steps:

1. Food prepared in unhygienic circumstances that endangers human health is tainted food.
2. It is illegal to import tainted food into interstate commerce.
3. The punishment for this violation of the Federal Food, Drug, and Cosmetic Act is up to a year in jail, a $1,000 fine, or both. A violation after a prior final conviction, or done with the purpose to defraud or mislead, is punishable by imprisonment for no more than three years, a fine of no more than $10,000, or both.

Specialist Food Legislation: EU Regulation 852/2004 on Food Hygiene. Regulation 852/2004 serves as a link between the GFL and more detailed EU hygiene regulations.

It serves four purposes: It specifies fundamental food hygiene guidelines for all phases of the manufacturing process. It requires food industry owners to establish, execute, and maintain a permanent method based on HACCP principles. It also encourages the creation, assessment, dissemination, and periodic revision of national and Community good practise guidelines for hygiene or the use of HACCP principles. § The fourth purpose is to specify which issues require more law.

These more stringent hygiene standards cover animal-derived foods, governmental controls, microbiological criteria for products, and a variety of other topics.Primary producers are distinguished from food industry operators at later levels of the food chain by the Primary Producers and Food Hygiene Regulation (EC) No. 852/2004. Primary producers are not required to implement HACCP-based methods. They are subject to a basic set of hygiene regulations for resource extraction and allied processes, as detailed in Annex I.

The general hygiene obligation is to safeguard basic items from contamination as much as possible. Every further processing qualifies this task.Food business operators must comply with Community and national legislative provisions governing the control of hazards in primary production and associated operations, such as measures to control contamination caused by air, soil, water, feed, fertilisers, veterinary medicinal products, plant protection products, biocides, and waste storage, handling, and disposal.Food business operators producing or harvesting plant products must keep clean and, if necessary, disinfect facilities, equipment, containers, crates, vehicles, and vessels; use potable or clean water; ensure that staff handling foodstuffs are in good health and receive health risk training; and prevent animals and pests.

Hygiene requirements Regulation (EC) No. 852/2004, Annex I, Part A. Innovations in Fresh-Cut Fruits and Vegetables Processing prevent contamination; and appropriately apply plant protection agents and biocides. When errors are discovered during official controls, they must take appropriate corrective action.Food business owners are required to keep records of risk-control measures and to provide this information to the appropriate authorities upon request.Information on the usage of plant protection agents and biocides, the prevalence of pests or diseases that may impact the safety of plant-derived products, and the findings of studies of samples relevant to human health are especially crucial.

After Primary Production and Food Hygiene, All Producers The food hygiene prescriptions of Annex II must be followed by food industry operators operating after primary production. This is a detailed collection of regulations divided into twelve chapters that cover all areas of food hygiene.The following is an example of food hygiene law for food business operators from Chapter I on general food premises requirements:

1. Food establishments must be kept clean and in excellent shape.
2. The layout, design, construction, siting, and size of food premises must: (a) allow for adequate maintenance, cleaning, and/or disinfection, avoid or minimise airborne contamination, and provide adequate working space to allow for the hygienic performance of all operations; (b) be such that it protects against dirt accumulation, contact with toxic materials, particle shedding into food, and the formation of condensation or undesirable mould on surfaces; and (c) be such that it protects against the formation of condensation or undesirable. The whole Chapter V Equipment requirements are a second example of Annex II rules:

1. All items, fittings, and equipment that come into contact with food must: (a) be thoroughly cleaned and, if required, disinfected. Cleaning and disinfection must occur at a frequency sufficient to avoid any risk of contamination; (b) be constructed, be made of such materials, and be kept in such good order, repair, and condition as to minimise any risk of contamination; (c) with the exception of non-returnable containers and packaging, be constructed, be made of such materials, and be kept in such good order, repair, and condition as to enable them to be kept clean and, if necessary, to be dilute
2. Whenever necessary, equipment must be equipped with any relevant control mechanism to ensure that the objectives of this Regulation are met.
3. Chemical additives must be used in line with good practise when used to prevent corrosion of equipment and containers.

The EC food hygiene regulation is complemented with a series of executive explanations. A guidance paper produced by the Commission's Standing Committee of Representatives and the Member States on the civil servant level explains Regulation (EC) No. 178/2002. The three examples below explain various aspects of Regulation (EC) No. 852 on food hygiene:

1. Guidance paper on the execution of some aspects of Regulation (EC) No 852/2004, European Community Commission, Health and Consumer Protection Directorate General On food hygiene,
2. Guidance document on the implementation of procedures based on the HACCP principles, and on the facilitation of the implementation of the HACCP principles in certain food businesses, European Community Commission, Health and Consumer Protection DirectorateGeneral, Brussels,
3. Guidance document on several critical topics relating to import requirements and the new regulations on food hygiene and official food controls, European Community Commission, Health and Consumer Protection DirectorateGeneral,

National and Community Food Business Operator Organization Guidelines

Regulation 852/2004 on food hygiene provides organizations of food industry operators with the opportunity to create national and Community guidelines to excellent food hygiene practice or to use HACCP principles. These guidelines are an important tool for achieving the food hygiene goals of Regulation 852/2004.The guidelines are entirely voluntary: food service providers are not required to contribute to their creation. When other food industry associations create guidance, they do so on a voluntary basis. The guidelines do not supersede the legal requirements of food industry owners, but rather assist them in meeting such obligations. The member states must encourage food business operators' groups to create national guidelines. The Commission must do the same at the EC level, but only after a dialogue with member states has determined the use of Community Guidelines, as well as their scope and subject matter.

For the production of national and Community guidelines, the applicable Codes of Practice of the Codex Alimentarius must be used. The European Commission wishes to contribute to the advancement of international food legislation. The guidelines are created using comparable methods. Organizations of food business operators provide national guidelines. The member states evaluate their draughts to ensure that the guidelines are developed in conjunction with representatives of groups whose interests are significantly affected, such as other food business operators, consumer organisations, and public agencies. The member states transmit approved national guides to the European Commission, who registers them in a system accessible to the member states. The organisations of food business operators that created the national guidelines spread them.

In a similar manner, the Community Guidelines are created with the cooperation of the Commission. The Community guidelines must be evaluated in conjunction with the member states before being acknowledged by the Commission. The Commission has issued recommendations for creating Community guides.Community guide titles and references are published in the C series of the Official Journal of the European Union. The guidelines will be made accessible to the public on a special page of the Commission's Health and Consumers Directorate-(DG General's SANCO) website.National guide references are published in the Registry of National Guides on Good Hygiene Practice.It provides a 38-page table with an overview of guides in the member countries, including the following information: title (original), title (English), country, language, publisher, edition, ISBN, ISSN, Internet or other contact, and key phrase.

As an example, consider the following:

Manuale di corretta prassi igienica per I centri di lavorazione e confezionamento dei prodotti ortofrutticoli freschi, surgelati, degli agrumi della frutta a guscio ed essiccata. Title (English): Handbook to Good Hygiene Practice for processing and packaging centres for fresh, frozen, washed-cut-and-packed fruits and vegetables, citrus fruits, nuts and dried fruit. The Associazione nazionale esportatori I portatori ortofrutticoli e agrumari (ANEIOA) published it in June 1999 with the internet address www.ministerosalute.it and the key term Fruit and Vegetables. The European Commission issued registration guidelines for

Because they can be found in ready-to-eat food, safeguards must be taken. The bacteria *Listeria monocytogenes* is one of these germs; it can live at low temperatures and kills one out of every five people it infects.The goal of many aspects of food law, such as hygiene codes, good practises, general hygiene laws, and specialised legislation, is to reduce microbial dangers. Commission Regulation (EC) No. 2073/2005 on microbiological standards for foodstuffs* is an example of legislation that supplements the broad requirements of hygiene Regulation EU No. 852/2004 with defining details. This is done in the framework of proper hygiene practise and the use of processes based on hazard analysis and critical control point (HACCP) principles. "A preventative strategy is mostly used to assure food safety." This method and the use of microbiological criteria to evaluate the proper operation of HACCP processes and good hygiene practise can strengthen each other. Yet, microbiological criteria are also used to remove defective foods from the market and to manage cleanliness.

CHAPTER 3

PREVENTATIVE STRATEGY

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The preventative strategy necessitates the use of effective good hygiene practises. Microbial Contamination Specific LawThe CAC has issued guidelines on microbiological criteria for foods and the assessment of microbiological risk.The Codex standard for microbiological criteria is followed by EC law.It is also based on studies and conclusions of European Commission committees and panels on the dangers of various forms of microbiological contamination of raw fruits and vegetables. *Listeria monocytogenes* is one of these categories, and opinions on the hazards associated with this organism were initially offered for food of animal origin, but were later extended to all foods.These opinions have been updated by an opinion from the European Food Safety Authority's competent panel.

The Commission Regulation (EC) No. 2073/2005 establishes food safety requirements for the presence of certain bacteria, as well as their toxins and metabolites, in twenty-seven distinct food categories. The rule introduces two types of microbiological criteria: process hygiene criteria that show the proper operation of the manufacturing process and food safety standards that determine the marketability of goods.Process hygiene requirements require food industry operators to implement steps based on their HACCP approach and good hygiene practise while supplying, handling, and processing raw materials and products.Food business owners must ensure that their products fulfil food safety standards throughout their shelf life.This obligation extends to all stages after manufacture, including distribution, storage, and sale. It addresses the usage of food and reaches the consumer's home, where the refrigerator temperature is frequently excessively high, which is a major source of microbial contamination. The food safety guidelines take this into consideration. The duty is confined to the situations that are reasonably foreseeable.

Food company operators in the manufacturing stage of the production chain must undertake research to see whether their products match the standards over the course of their shelf life. This responsibility is especially applicable to ready-to-eat goods that can enable the growth of Listeria and may endanger public health. The European Commission created a guideline, and the Community Reference Laboratory for *Listeria monocytogenes* created a technical guideline for laboratories undertaking shelf-life research. When confirming the correct operation of the HACCP-based method, food industry operators must execute tests against the microbiological requirements of Annex I.as well as the appropriate hygiene practises they employ. In the framework of this technique and practise, they must determine the proper sample frequencies. They must also consider what the food's usage instructions will be.

The Commission Regulation (EC) No. 2073/2005 establishes the requirements of food company operators to ensure that their goods fulfil microbiological criteria and specifies the detection techniques they must apply. The detection procedures for food samples are based on particular International Organization for Standardization (ISO) standards. When necessary, samples must be gathered from processing areas and equipment, and ISO Standard 18593 is the reference procedure. The number of sample units is defined in Annex I, however the food company operator can lower the quantity if the producer can demonstrate that effective HACCP-based processes are employed through historical documentation.

Other sampling and testing methodologies may be used by food company operators if they can satisfy the competent authorities that they give at least similar assurances. Alternative analytical methods are acceptable if they have been validated against the reference method specified in Annex I and the operator employs a proprietary method certified by a third party in accordance with the protocol of ISO standard 16140 or other internationally accepted similar protocols. Alternative analytical procedures are acceptable if they have been verified against internationally accepted protocols and approved by the appropriate authorities.With regard to two bacteria, FcFV is on the Annex I food safety criterion list. With connection to Salmonella, a food safety criteria has been established for precut fruits and vegetables (ready-to-eat). Food safety precautions are made against *Listeria monocytogenes* in three food groups. The first group includes ready-to-eat meals designed for newborns and particular medical needs. In this food category, fresh, uncut, and unprocessed vegetables and fruits do not require routine testing under typical conditions. Fresh-cut vegetables, by implication, requires regular testing.

The two remaining categories of ready-to-eat food are for food that is not meant for newborns or for particular medical uses. Food category 1.2, ready-to-eat meals that can promote the development of *Listeria monocytogenes*, will be examined on a regular basis. This category's test result is satisfactory when the food company operator can demonstrate that the product will not exceed the limit of 100 cfu/g throughout its shelf life. When the operator is unable to demonstrate this condition, the following test results apply before the food has left the producer's immediate control: a satisfactory result if all observed values indicate the absence of the bacterium, and an unsatisfactory result if it is detected in any of the sample units.

is the inability of ready-to-eat meals to sustain the development of this bacteria. This category automatically includes products with a specific acidity and water activity or a shelf life of fewer than 5 days. Additional product categories may be added if scientifically justified. Fresh-cut vegetables must be tested on a regular basis, although the findings are less strict. They are acceptable if all of the observed values are less than or equal to the limit of 100 cfu/g.

This bacteria cannot grow in ready-to-eat meals. This category automatically includes products with a predefined acidity and water activity as well as those having a shelf life of fewer than 5 days. When scientifically warranted, further product categories can be added. Fresh-cut food must undergo regular testing, although the findings are less strict. They are adequate if all of the observed values are less than or equal to the limit of 100 cfu/g.an extreme example, because the legislation in this case does not only allude to or integrate a portion of a known practise, but determines it word for word, sentence for sentence, as enforceable legislation.

Processors that make, process, pack, or store human food must follow certain food safety guidelines. This indicates that this legislation does not apply to agricultural production procedures. It does cover the manufacture of FcFV.

The CGMP specifies the responsibilities of those in charge of food production in order to ensure the highest possible levels of food hygiene. It specifies guidelines for all stages of food processing after harvesting for all people and items that can have an impact on food hygiene. CGMP is used in buildings or other facilities where human food is prepared, packed, labelled, or stored. All possible steps and means must be taken to ensure that the employees working in those facilities report their health status, maintain cleanliness, and are educated and taught in proper food handling and food safety standards.

The FDA issued the 2008 "Guide to Reduce Microbial Food Safety Risks of Fresh-Cut Fruits and Vegetables" as a collection of nonbinding recommendations to the industry. It is one of the tools utilised by the FDA to address fresh produce food safety issues. Additional tools include the 1998 "Guide to Reduce Microbial Food Safety Risks for Fresh Fruits and Vegetables" (USA FFV Guide 1998) and the 2005 "Letter to California Companies That Produce, Pack, Process, or Ship Fresh and Fresh-cut Lettuce".

The instructions are not legally enforceable and do not provide any rights or duties for manufacturers, the FDA, or the national govt. These only represent the FDA's most recent considered information. Producers that have alternatives are encouraged to contact the FDA to discuss them. § The guidelines are recommendations for food safety measures that fresh-cut produce processors can use to satisfy the mandated CGMP criteria. The instructions can go into additional information about aspects that are particularly important to FcFV manufacturers. The regulatory CGMP is designed for a wide range of goods. The CGMP, a six thousand word manual, may be envisioned as the regulatory core, established on federal legislation and surrounded by many guides detailing the regulation on different groups of product.

The CGMP is explained in fifteen thousand words in the fresh-cut produce guide, and thirty-two thousand words in the fresh produce guide from 1993.In addition to giving producers with tailored counsel, the two manuals also playa part in the regulatory style defined by the FDA to attain the appropriate level of food safety using a mix of instruments.The FFV Guide USA of 1998 was followed by FDA letters to producers of fresh lettuce that was processed into fresh-cut lettuce informing them that substantial food safety occurrences in their region were caused by food hygiene violations. Individual firms could not be linked to the items. The letters urged manufacturers to follow the obligatory hygiene guidelines and expressed the FDA's "serious concern about the ongoing occurrences of foodborne disease related with the use of fresh and fresh-cut lettuce and other leafy greens." The letters were used by the government to define its goals and to specify the measures it expects the industry to do to improve the safety of these goods. It warns producers that it is reviewing its regulatory options and will consider taking enforcement action against enterprises and farms who cultivate, pack, or process fresh lettuce and leafy greens in unclean circumstances.

Another example of this "hands-off" approach is the adoption of the HACCP system. The FDA points out that US law does not force FcFV manufacturers to use the HACCP system. At the same time, it refers favourably to the United Fresh Produce Association's suggestion to utilise HACCP, as well as information that most growers do.Law can directly promote the adoption of standards by referring to them as technical rules that must be followed in order to carry out the legislation. Law can indirectly encourage the application of standards by including principles such as due diligence into food legislation.

After a string of severe food safety issues, the United Kingdom's government took this action. The principle of due diligence shifts the burden of proof. It implies that a food company operator can defend himself in any case for an infringement under the Food Safety Act 1990 by demonstrating "that he took all reasonable measures and exerted all necessary effort to avoid the commission of the offence by himself or by a person under his control."

This served as a catalyst for a more systematic approach to food safety concerns, with a focus on prevention and the compilation of verifiable records of good practises. That prompted the British Retail Consortium (BRC) to develop the Food Technical Standard, which allows retailers to assess the work of producers of their own brand of food goods. This was simply the first in a series of BRC food-related criteria. The Global Standard for Food Safety and the Global Standard for Packaging and Packaging Materials, both released in 2008, are the most recent representations.

The G.A.P. Global Standard

The GlobalG.A.P. organisation, the worldwide successor of EurepGAP, an effort by a group of top European retailers to transfer their customers' and some of their own preferences to primary producers, established a comprehensive mix of tools for food safety and quality.GlobalG.A.P. is a GAPractice, an adaptation of the HACCP system to primary production, a certification standard, and, lastly, a farm insurance contract.Farmers and producers that engage in the plan are required to audit their operations at least twice a year against the Global G.A.P standard. First, self-assessment, and then certification with an independent certification agency chosen by the GlobalG.A.P. organization.

The control points and compliance requirements are structured into three frameworks based on expertise in the manufacturing processes. Section AF, the "All Farm Basis," is the initial framework, and it covers the main features of primary agriculture.The second framework includes various components of broader product groupings including CB Crops Base," LB "Livestock Base," and AB "Aquaculture Base." Each of these categories is further broken into a number of distinct items that comprise the third framework.The first particular product group in the "Crops Base" is Section FV "Fruit and Vegetables." Collecting the 236 possible control points for fruits and vegetables from the "All Farm Base," "Crops Base," and FV "Fruit and Vegetable Section" yields the 236 potential control points.They begin by keeping records and creating a reference system for each field, orchard, and greenhouse. This gives the required information for traceability, which is one of the merchants' primary concerns. Below are some examples of control points and their compliance criterion:

Spoilage Pattern and Spoilage Microorganisms Related to Fresh-Cut Fruits and Vegetables

There are two basic patterns of deterioration in fresh-cut fruits and vegetables that are distinct yet impact each other. It is necessary to distinguish between physiological spoiling (caused by the enzymatic and metabolic activities of live plant tissue) and microbiological spoilage (due to proliferation of microorganisms).The natural protection of the epidermis is removed during processing of fresh fruits and vegetables, as is the internal compartmentalization that separates enzymes from substrates. Plant tissues incur physical damage as a result, making them far more perishable than when the original product is intact.

Moreover, processing results in a stress response by the produce characterised by an increased respiration rate (wound respiration) and ethylene production, leading to faster metabolic rates. In addition to these changes in metabolic rates, plant tissue injury causes exposure to air, desiccation, and the association of enzymes with substrates, all of which contribute to quality deterioration (Klein 1987; King and Bolin 1989; Roura et al. 2000; Knee and Miller 2002). In addition to physiological functions, the release of nutrients on the wounded surfaces permits microorganisms to thrive. In normal conditions, the outer layer of plant tissue has a hydrophobic surface, which acts as a natural barrier for microbes. As a result of surface injury, nutrients are released from plant tissue and can be utilised by bacteria, as demonstrated by Mercier and Lindow (2000) after inoculating Pseudomonas fluorescens on various leaves of vegetable plants. Microorganism densities were closely connected to the amount of sugars present on the surface of leaves, and these sugars were the limiting factor in terms of colonization. Basic et al. (1996) discovered microbial populations on cut surfaces of spinach after 12 days of storage at 10°C in relation to the presence of damaged regions. When inoculating celery, Brocklehurst and Lund (1981) discovered that soft rot could not be generated on unwounded tissue, presumably because to restricted proliferation.

Plant tissue damage provides a better substrate for microbiological development by giving nutrients. Certain microbes create pectin lytic enzymes that degrade texture, providing more nutrients for microbiological action (e.g., during soft rotting, spoilage of leafy vegetables such as fresh-cut lettuce). Commodities prone to high nutrient release will experience severe microbial proliferation (for example, during rotting of aggressively sliced fruits and vegetables such as cucumber cubes, zucchini slices, and melon pieces). Moreover, large microbial loads might cause increased respiration rates in produce, as demonstrated by Saftner et al. in the instance of fresh-cut melon. Yeasts and molds, which are less susceptible to low pH, will grow on lower pH fruits, whereas bacterial growth can be observed on more pH-neutral vegetables.

Fresh-Cut Fruits and Vegetables: Microbiological and Safety Considerations

The intrinsic features indicated above (for example, tissue pH and nutrient availability) dictate the development rate and kind of microbes that form on the product, and hence the sort of spoiling pattern. Extrinsic factors (such as storage temperature and gas environment) also have an impact on the rotting behaviour of fresh-cut fruits and vegetables. In terms of microbiological processes, Zagory (1999) analyzed various fresh-cut vegetable tests, demonstrating that the influence of changed environment on microbiological development is inconsistent and that storage temperature, rather than gas composition, affects microbiological growth.

Moreover, Nguyen-the and Carlin indicated that the benefits of changed atmosphere for quality are not consistently associated with a reduction in mesophilic flora development. According to Bennik et al. (1998), the physiological condition of the product, rather than soft-rot bacteria suppression, plays an essential role in the favorable benefits of controlled environment storage of vegetables. Yet, too little O2 or too much CO2 might cause physiological problems that are unrelated to microbial activities.

According to Rocha et al. the microbial population does not promote spoiling in fresh-cut oranges, at least when adequate temperatures are used. Rather, some components in the fruit, in combination with variables acquired during processing (e.g., enzyme inhibition), may promote spoiling. Pretel et al. discovered similar results (1998). The common gas conditions used for packing fresh-cut fruits and vegetables, 3% to 5% O2, mixed with 5% to 10% CO_2 (and balanced by N_2), have no direct effect on produce microbiological development. The good effect of changed environment on fresh-cut product quality and spoiling retardation is related to the reduction of metabolic activity of living plant tissue. As a result, plant tissue retains its inherent strength and protection for a longer period of time (Jacxsens et al. 2002a, 2002b, 2003). Spoilage of fresh-cut fruits and vegetables will thus be dictated by the rate of physiological and microbiological processes, since there is a probable interaction between these two processes in the case of fresh-cut vegetables.

An Outline of the Most Significant Spoilage-Related Microorganisms

Seed, soil, irrigation water, animals, manure/sewage sludge usage, harvesting, processing, and packing are all potential contamination sources for fresh-cut fruits and vegetables. After processing, total counts of microbiological populations on fresh-cut vegetables vary from 3 to 6 log CFU/g.During storage, the bacterial community is dominated by Pseudomonadaceae (particularly P. fluorescens) and Enterobacteriaceae (particularly Erwinia herbicola and Rahnella aquatilis), with some lactic acid bacteria (particularly Leuconostoc mesenteroides) also present. Unlike bacteria, numerous distinct yeast species have been detected in fresh-cut vegetables, including Candida sp., Cryptococcus sp., Rhodotorula sp., Trichosporon sp., Pichia sp., and Torulaspora sp.

Fresh-Cut Fruits and Vegetables Advances Processing

Molds are less important in fresh-cut vegetables due to inherent qualities that promote the growth of bacteria and yeasts. Fresh-cut fruits have intrinsic qualities that promote the growth of yeasts, moulds, and, in certain situations, lactic acid bacteria, owing to their lower pH value as compared to vegetables. For processed fruits, Tournas et al. discovered yeast levels ranging from less than 2 to 9.72 log CFU/g in the majority of 38 fruit salad samples (cantaloupe, citrus fruits, honeydew, pineapple, cut strawberries, and mixed fruit salads). Pichia sp., Rhodotorula sp., Candida pulcherrima, C. lambica, C. sake, and Debaryomyces polymorphus were the most frequent yeasts. Molds of many types can be seen on fruits. Botrytis cinerea, Rhizopus stolonifer, Mucor piriformis, Rhizoctonia solani, and Phytophtora cactorum have all been found on berries.

Penicillium and Cladosporium species can infest overripe or damaged fruit (Pitt and Hocking 1997). Bacterial survival and proliferation on the calyx of strawberries is feasible on intact strawberry and raspberry fruit.

Deterioration Process

Several methods describe microbiological proliferation: The synthesis of enzymes and metabolites causes visual and textural flaws as well as off-odors. The interplay with physiological systems is crucial in this case. For example, on fresh-cut vegetables that are susceptible to enzymatic browning, settings that reduce the pace of this physiological process decide whether browning affects the sensory shelf life of the commodities. Lower O_2 concentrations inhibit enzymatic browning, therefore sensorial quality criteria other than browning (e.g., microbiological creation of off-odors) become relevant in terms of sensorial shelf life. Grated celeriac, for example, grew unacceptably brown before off-odors could be recognised due to great sensitivity to browning. Similarly, the whitening and loss of fruity scent on fresh-cut carrots happened before the emergence of off-odors.

The sort of rotting will also be determined by the composition of the fruits and vegetables. Growth of yeasts and lactic acid bacteria is favoured in sugar-rich products such as carrots, bell peppers, and most freshcut fruits, resulting in off-odors caused by microbial proliferation and the production of acids such as lactic acid, acetic acid, malic acid, succinic acid, and pyruvic acid (Carlin et al. 1989; Kakiomenou et al. 1996). As can be shown, the identification of off-odors is frequently accompanied with a bacterial count greater than 8 log CFU/g or a yeast count greater than 5 log CFU/g.Carlin et al. (1989), Barry-Ryan and O'Beirne (1998), and Hao et al. (1999) all asserted this in the instance of fresh-cut carrots. Organic acid production on shredded mixed bell peppers and grated celeriac was discovered when the psychrotrophic population approached 8 log CFU/g, with lactic acid bacteria dominating.

At the point of deterioration, yeasts in bell peppers topped 5 log CFU/g (Jacxsens et al. 2003). Sourness is frequently accompanied by water loss, which is frequently connected with the growth of L. mesenteroides.In addition to organic acids, bacteria and yeasts may produce ethanol, as proved by Jacxsens et al. (2003) on a mixed-lettuce agar simulated media. Ethanol synthesis is frequently coupled with the creation of additional volatile organic molecules such as 2-methyl-1-propanol, 2-methyl-1-butanol, and 3-methyl1-butanol, which could be identified from bacteria at 8 log CFU/ cm2 and yeasts at 5 log CFU/ cm2 (Ragaert et al. 2006a). At 20°C, Smyth et al. (1998) observed inedible lettuce due to significant fermentation and bacterial multiplication (no counts given).

Among the volatile organic substances found were 2-methyl-1-butanol, 3-methyl-1-butanol, and 3-methyl-1-pentanol. It was unclear if these chemicals were produced physiologically or microbiologically. Freshcut fruits, which contain high amounts of fermentable sugars, are frequently characterised by off-odors caused by yeast development, which results in the generation of volatile organic compounds such as ethanol. Remarkably, yeasts inoculated on a strawberry simulation medium generated the same chemicals as reported on mixed-lettuce agar (ethanol, 2-methyl-1-propanol, 2-methyl-1-butanol, and 3-methyl-1-butanol) from 5 log

CFU/cm2 (Ragaert et al. 2006b). With yeast growing to 5.5 log CFU/g, increasing quantities of ethanol were found on fresh-cut apples. Molds decide spoiling in some circumstances (e.g., temperature abuse, significant initial contamination of moulds), resulting in visual deterioration before yeasts or bacteria may cause off-odors (Nielsen and Leufvén 2008). Metabolite formation is frequently accompanied with sugar consumption by microbes, as demonstrated by Tassou and Boziaris (2002), Jacxsens et al. (2003), Piga et al. (2003), Soliva-Fortuny et al. (2004), and Shah and Nath (2008) for litchis, carrots, apples, and litchis, respectively.

Independent of microbiological counts, production of fermentative metabolites such as ethanol is also conceivable owing to fermentation reactions of produce when kept at too low O2 concentrations or too high CO_2 concentrations. López-Gálvez et al. demonstrated this in the case of packed salad items (ethanol and acetaldehyde) and Smyth et al. in the case of chopped iceberg lettuce (ethanol, acetaldehyde, ethyl acetate). According to Smyth et al. (1999), the presence of ethanol on fresh-cut carrots is a wounding reaction. Mechanical injury of fruits and vegetables (e.g., cutting) stimulates a wide range of enzymatic pathways, many of which are linked with the production of volatiles (Toivonen 1997). According to Purvis (1997), various variables, including environmental (freezing injury temperature, hypoxic circumstances), biotic (microbial infections), and internal (ripening, senescence), can increase fermentative metabolism in fruits.

Metabolite formation can also influence physiological processes, as evidenced by storage tests with strawberries, which revealed that ethanol was converted to ethyl acetate by physiological processes, limiting the sensory shelf life of strawberries. When yeast counts exceeded 5 log CFU/g, ethanol levels increased. Items with lower sugar content, such as lettuce, will be damaged mostly by soft-rot bacteria such as Pseudomonas sp., resulting in both textural and visual flaws, however these bacteria may also create metabolites, resulting in offodors as stated above. Apart from physiological texture degradation, many bacteria create pectinolytic enzymes that impact textural changes in fresh-cut produce by degrading the pectin molecule in the intermediate lamella and the main cell wall. This has been documented for many bacteria species. Erwinia and Pseudomonas species are the most commonly identified pectinolytic bacteria in fresh-cut vegetables.

Moreover, a wide variety of yeasts have been identified as makers of pectinolytic enzymes, namely endopolygalacturonases, which may be crucial to consider during fresh-cut fruit storage. The softening of the tissue caused by microbial activity occurs where nutrients are abundant (e.g., on the cut surfaces). The numbers required to cause textural deterioration appear to be inconsistent. Bacterial populations ranging from 7 to 7.7 log CFU/g were discovered on celery segments, with the pectinolytic Pseudomonas sp. predominant. Soft or macerated tissue accompanied this. Babic et al. (1996) discovered texture degradation in freshcut spinach when the microbiological count surpassed 8 log CFU/g, with Pseudomonas fluorescens dominating. Robbs et al. (1996b) discovered 7.1 log CFU/g bacterial populations on fresh-cut celery but no deterioration in terms of texture or colour, despite the fact that the dominating flora included pectinolytic Pseudomonas sp. Pectinolytic bacteria isolated from fresh-cut (grated) carrots had no effect on spoiling, presumably due to the dominance of lactic acid bacteria and yeasts.

In the instance of cut celery, Robbs et al. indicated that a diverse combination of bacteria rather than a single pathogenic species will commence decay, but Robbs et al. stated that a probable reduction in plant resistance to microbiological attack might lead to the development of decay. It should also be noted that physiological processes or the activity of pectinolytic bacteria that cause "soft-rot" patches or other visual symptoms might result in intolerable visual defects before textural variations can be seen. Furthermore, reports combining different sensorial evaluations, including texture, discovered that visual defects or off-odor and off-flavors determined sensorial shelf life during storage experiments with soft red fruits and different fresh-cut vegetables. Several publications have shown that gas composition can affect the texture of fruits and vegetables. Nevertheless, it is not feasible to draw inferences from these papers on which gas composition is ideal, presumably because to the reliance on multiple characteristics such as product type, cultivar, and tolerance to high CO_2 and low O_2 concentrations.Several publications state that visual abnormalities become obvious with a microbiological count of 8 log CFU/g.

CHAPTER 4

ASSOCIATION OF PATHOGENS WITH CONSUMPTION OF (FRESH-CUT) FRUITS AND VEGETABLES

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Fresh-cut fruits and vegetables are frequently regarded as microbiologically safer food products than food of animal origin or other ready-to-eat food goods. However, some recent foodborne outbreaks have resulted in scientific and commercial stakeholders considering fresh-cut fruits and vegetables as possible vehicles of foodborne pathogens (e.g., norovirus outbreak due to frozen raspberry fruit in Scandinavian countries in 2006, outbreak of Escherichia coli O157:H7 associated with fresh spinach in the United States in 2007, and Salmonella outbreak in the United States with tomatoes in 2008).

The raw intake of the items, the use of moderate processing procedures, and the subsequent storage time provided novel habitats and possible infection vehicles for indigenous and pathogenic microbes. Fresh-cut fruits and vegetables have swiftly achieved a substantial market share due to their strong marketing features, frequently without comprehensive study of the safety concerns of this type of product. Pathogens may be present on raw vegetables or during processing owing to cross-contamination. The mechanisms by which fresh produce can become contaminated with pathogenic microorganisms and serve as vehicles for human disease. Typical transmission routes in primary production include water, soil, or sewage contaminated with faecal (enteric) pathogens such as Salmonella spp., E. coli, and viruses. During harvesting and subsequent processing (Figure 4.1).

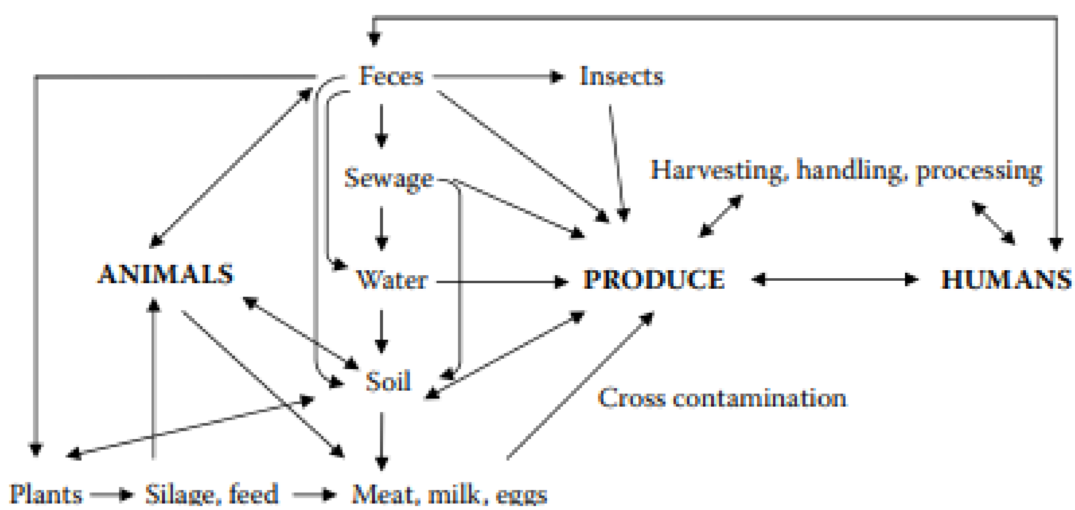

Figure 4.1 represents the Pathogens with Consumption

Humans and materials can both cause pollution. It is often assumed that these gastrointestinal pathogens would not fit in with natural plant-associated bacteria, however recent study has shown that they may thrive and remain on agricultural plants (Brandt 2006).

Internationalization of the Fresh Food and Vegetable

Fresh-cut fruits and vegetables are being associated with food poisoning due to increased consumption, improved consumer knowledge of the benefits of fruits and vegetables in their diet, and convenience. Furthermore, the internationalization of the fresh produce supply chain has resulted in a broader range of fresh produce being available throughout the year. Increasing globalization also entails longer time intervals between harvest, processing, and consumption, necessitating the adoption of well-controlled storage and long-distance transit conditions. Natural plant protective barriers are destroyed by processing procedures such as cutting, slicing, and shredding, giving a perfect setting for microbial development. These processing stages also increase the possibility of cross-contamination.

In general, fresh-cut fruits and vegetables are relatively infrequently implicated in foodborne outbreaks in Europe (European Food Safety Authority [EFSA] 2007; Rapid Alert System for Food and Feed [RASFF] 2007). According to the EU's yearly Rapid Alert reports, the relative proportion of alarm notifications for fruits and vegetables remained consistent at around 9% from 2000 to 2005. In 2006, 72 warning notices involving fruits and vegetables were registered. Yet, the majority of them were linked to the presence of mycotoxins or pesticide residues.Pathogenic bacteria, particularly Salmonella, were only discovered in third place (RASFF 2007). In the United States, the number of documented produce-related outbreaks climbed from two per year in the 1970s to seven in the 1980s and sixteen in the 1990s. Fresh produce is the second most major food product (22%) related with foodborne outbreaks in the United States, behind seafood (33%), and is followed by chicken (18%), beef (16%), and eggs (13%). Salad, lettuce, juice, melon, and sprouts were the produce kinds most commonly linked in produce-related epidemics. Many pathogens have been linked to produce-related outbreaks, with Salmonella and E. coli O157:H7 being the most common in the US (Sivapalasingam et al. 2004). The striking discrepancy between the European and American circumstances can be attributed to a variety of factors. A solid, established information collection system exists in the United States, but the Rapid Alert System began in Europe in 2005. Variations in primary production methods, water management systems, and relationships between primary production and the freshcut business may help explain some of the disparity between US and EU estimates. The investigation of outbreaks associated with fresh produce is frequently difficult because they are typically geographically diffuse (the product has a wide distribution pattern); there is a low attack rate (the product has a low level of contamination); and, due to its short shelf life and rapid turnover, the implied product or even product originating from the same batch is rarely available by the time an outbreak has been identified (Tauxe et al. 1997).

According to EFSA, foodborne viruses (specifically, adenovirus, norovirus [NoV], enterovirus, hepatitis A virus [HAV], and rotavirus) are responsible for 593 outbreaks out of a total of 5,710 recorded foodborne outbreaks in Europe in 2006, accounting for 10.2% of all reported outbreaks. In all, 13.345 people were part in Microbiological and Safety Aspects of Fresh-Cut Fruits and

Vegetables 63, making foodborne viruses the second most significant agent after Salmonella (EFSA 2007). NoV, HAV, rotavirus, and astrovirus are among the thirteen primary foodborne diseases listed by the Centers for Disease Control and Prevention (CDC) in the United States (Mead et al. 1999). These viruses account for nearly 67% of all foodborne infections in the United States, with NoV being by far the most significant cause. Outbreaks have been linked to coleslaw, tossed salad (White et al. 1986), green salads (Griffin et al. 1982), green onions (Wheeler et al. 2005), fresh-cut fruit (Herwaldt et al. 1994), small soft fruits such as raspberries (Gaulin et al. 1999; Korsager et al. 2005; Cotterelle et al. 2005; Calder et al.

Cyclospora cayetanensis caused the greatest foodborne outbreaks caused by protozoan parasites in North America during the late 1990s. The epidemic was traced down to fresh raspberries imported from Guatemala (Herwaldt 2000). Although Cryptosporidium parvum and Giardia lamblia are more likely to induce waterborne outbreaks, outbreaks have been linked to green onions (Quinn et al. 1998) and basil (Lopez 2001).Salmonella and Shigella spp. are pathogens found in mesophilic faeces. Temperature abuse (T > 10 to 12°C) is mostly responsible for their development on fresh-cut veggies.Shigella sonnei and S. flexneri have been found to have minimum growth temperatures of 6°C and 7°C, respectively (ICMSF 1996). Fruits' low pH limits their growth (save for melons, which have a high pH and have been linked to Salmonella epidemics). Although being very fragile, certain Shigella strains may endure acidic environments, with pH 4.5 (Bagamboula et al. 2001) and pH 5 (ICMSF 1996) being the lowest documented pH for growth. The pathogen's infectious dosage is fewer than 100 cells. Shigellosis is often transferred from person to person, although it can also be contracted by the intake of contaminated water and foods, particularly salad greens. Imported food items from endemic locations with inadequate hygiene standards have become a potential source of Shigella infected foods (Smith 1987; ICMSF 1996). S. sonnei can thrive on shredded cabbage at temperatures ranging from 0 to 6°C for three days without dying. At 24°C, a rapid decrease in number was detected due to the pH drop of cabbage caused by the rapid expansion of spoiling bacteria (Satchell et al. 1990).

When Shigella spp. was inoculated onto several commercially prepared salads and vegetables (carrots, coleslaw, radishes, broccoli, cauliflower, lettuce, and celery), it survived for many days at both ambient (22°C) and refrigerated temperatures (5 and 10°C) (Rafii et al. 1995). S. flexneri survived for as least 11 days at 4°C on coleslaw, carrot salad, and potato salad (Rafii and Lunsford 1997). Tests at 12°C revealed that Shigella flexneri and S. sonnei were able to flourish on fresh-cut mixed lettuce and shredded carrots, but not on shredded bell peppers due to their lower pH. Only survival or a rare fall in numbers was seen at 7°C (Bagamboula et al. 2002). There was no difference in growth, survival, or die-off between air conditions and low O_2 and low CO_2 atmospheres.At temperatures below 15°C, growth is significantly slowed, and growth is stopped at temperatures below 7°C (ICMSF 1996).After 10 days of storage at 4°C, Piagentini et al. (1997) discovered that infected S. hadar survived on shredded cabbage, with an increase at 12 and 20°C.

The cabbage was wrapped in permeable packing material, which resulted in a steady-state environment of 1.5% O_2 and 8 to 10% CO_2. There was no substantial change in the population of S. Montevideo on the surfaces of tomatoes at 10°C (18 days storage), while growth occurred at 20°C (7 days storage). Finn and Upton (1997) discovered the lack of infected S. typhimurium after 2 days of storage at 7°C on shredded carrots and cabbage (1% O2 and >25% CO2). Lin and Wei (1997) revealed that Salmonellae, which were present on the surface of tomatoes and melons, were distributed in the tissue by cutting, posing a potential concern in precut goods. S. enteriditis, S. infantis, and S. typhimurium have all been shown to grow in chopped cherry tomatoes. In specific circumstances, these germs, along with several other Salmonella spp., were able to thrive at low pH (3.99 to 4.37) (Asplund and Nurmi 1991; Wei et al. 1995; ICMSF 1996). Refrigeration is the most effective means of preventing the spread of these mesophilic diseases.

Escherichia Coli

While raw and undercooked bovine foods are the primary dietary sources for Escherichia coli O157:H7, illnesses related with contaminated fruits, vegetables, and water have increased. E. coli O157:H7 was found in sprouts (alfalfa, mung bean, and radish) and vegetable salads (Lin et al. 1996). E. coli O157:H7 survival and growth patterns were affected by vegetable type, packaging environment, storage temperature, and bacterial strain (Francis and O'Beirne 2001). E. coli O157:H7 might grow on sprouting alfalfa sprouts maintained at room temperature for two days (Castro-Rosas and Escartn 2000; Charkowski et al. 2002). In surface wounds on several apple cultivars maintained at 24°C for 6 days, E. coli O157:H7 proliferated rapidly (Janisiewicz et al. 1999; Dingman 2000). During a 14-day storage period at 4°C, the E. coli O157:H7 population in shredded lettuce decreased by roughly 1 log.

Populations of the same E. coli O157:H7 strain rose by around 3 log at a higher temperature (22°C) within 3 days. Similarly, E. coli O157:H7 populations in lettuce held at 5°C reduced by around 1 log in 18 days but grew by about 3 log when lettuce was stored at 15°C. Another study found that E. coli O157:H7 could live for 14 days on newly peeled Hamlin orange with a pH of 6 to 6.5 at the surface (Pao et al. 1998). E. coli O157:H7 was able to proliferate on shredded lettuce, sliced cucumber, and shredded carrots at temperatures ranging from 12 to 21°C, as well as melon cubes at 25°C. E. coli O157:H7 could survive for 34 hours on melon cubes and up to 14 days on shredded lettuce, sliced cucumber, and shredded carrots at 5°C. The ability of E. coli O157:H7 to grow on produce at higher temperatures and survive at lower temperatures, together with its low infectious dosage (10 to 100 CFU/g), makes the presence of this pathogen in produce a significant concern to public health (Chang and Fang 2007). The survival and proliferation of E. coli O157:H7 are not affected by packaging fresh vegetables under adjusted air conditions. While changed environment packing improved the shelf life of shredded lettuce, the longer shelf life permitted E. coli O157:H7 to multiply in greater quantities over the shelf-life period as compared to air-held shredded lettuce (Diaz and Hotchkiss 1996).

Gunes and Hotchkiss discovered that E. coli O157:H7 thrived in fresh-cut apples but was inhibited in modified atmospheres with high carbon dioxide concentrations at harsh temperatures. In addition to the typical intrinsic and extrinsic characteristics, the degree of processing, such as the degree and method of cutting, influences the development of E. coli O157:H7 on fresh-cut fruit.Campylobacter spp. is the most prevalent cause of bacterial gastroenteritis globally, yet the pathogenesis of this infection is still partially understood. In addition to known risk factors such as consuming chicken meat and having contact with animals, less obvious risk factors such as eating raw vegetables (tomato, cucumber) and drinking bottled water were identified as risk factors for Campylobacter infections. Several investigations have been conducted to determine the prevalence of Campylobacter in fresh vegetables. Campylobacter spp. was not isolated from imported lettuce samples, prepared salads and vegetables, or Vietnamese vegetables during an examination of five varieties of fresh produce acquired at the retail level.

Another study looked at the incidence of Campylobacter spp. in a popular Malaysian salad meal from both a traditional wet market and two contemporary supermarkets. The average frequency of Campylobacter spp. in raw veggies from these areas was between 29.4% and 67.7% in this case. Campylobacter jejuni was recovered to a lesser extent from 1.5% of the studied fresh mushrooms (Doyle and Schoeni 1986) and 3.57% of Indian vegetable samples (Kumar et al. 2001). In Canada, thermotolerant Campylobacters were found in spinach (3.3%), lettuce (3.1%), radish (2.7%), green onions (2.5%), parsley (2.4%), and potatoes (1.6%) sold at farmers' outdoor markets, although retail samples were all negative (Park and Sanders 2002).Campylobacter in produce is caused by cross-contamination during the holding and packaging stages in supermarkets or kitchens, poor food handler hygiene, or contamination from contact with natural fertilisers or contaminated water.

Campylobacter spp. may live at refrigeration temperatures for lengthy periods of time in nutrient-limited conditions, despite their strict growth needs. This feature, together with the low infective dosage and microaerophilic nature of Campylobacter, indicates the potential importance of Campylobacter in chilled vegetables. Additionally, ready-to-eat veggies in modified atmospheric packaging are stored at high relative humidity, chilled (10°C) conditions, and a low amount of oxygen (5%). Since Campylobacter survives best at low oxygen concentrations, changed atmospheric packing may extend the pathogen's shelf life. Although Campylobacter survival in animal goods (milk, eggs, and meat) has been thoroughly examined, Campylobacter survival in fresh vegetables has been rarely studied. Kärenlampi and Hänninen (2004) were the lone researchers that investigated Campylobacter jejuni survivability on fresh food, such as fresh-cut iceberg lettuce, in their paper Microbiological and Safety Aspects of Fresh-Cut Fruits and Vegetables. 67 cantaloupe cubes, cucumber slices, shredded carrot, and strawberries. The mean mortality rates (day-1) at 7°C ranged from 0.41 to 1.02 log depending on the type of product (Kärenlampi and Hänninen 2004). At 21°C, the associated mortality rates varied from 1.52 to 8.74 day-1. Strawberry mortality rates were much greater than in other produce, most likely due to the lower pH (3.4) of strawberries compared to the other studied produce (5.8 to 6.8) (Kärenlampi and Hänninen 2004). Based on these findings, Kärenlampi and Hänninen (2004) concluded that Campylobacter jejuni may live in fresh products, especially strawberries, long enough to represent a risk to the consumer.

Listeria monocytogenes is rapidly becoming recognised as a source of foodborne sickness, and has been linked to significant outbreaks of infection. Listeriosis vectors have been detected in lettuce and other raw vegetables. Little et al. (1999) discovered that no *L. monocytogenes* was recovered from 151 samples of imported vegetables in the United Kingdom. The same results were achieved in Italy from 1989 to 1999 and in Canada on 100 lettuce, celery, radishes, and tomatoes samples (Farber et al. 1989). Prior to processing, the organism was seldom seen on vegetables (Fenlon et al. 1996). Yet, in Spain, 30% of 70 mixed lettuce samples tested positive for *L. monocytogenes* (Garcia-Gimeno et al. 1996). In Europe, the prevalence of *L. monocytogenes* in fresh-cut vegetables ranged from 0% to 19%. Francis et al. (1999) determined the infection level of fresh vegetables for *L. monocytogenes* to be 0% to 44%. Farber et al. investigated the ability of *L. monocytogenes* to survive and develop in various retail and wholesale packed fresh-cut vegetables at refrigerated temperatures (4 and 10°C). Carlin and Nguyen-the (1994) investigated the survival of *Listeria monocytogenes* on green leafy crops. Several studies have shown that *L. monocytogenes* can grow on modified atmosphere packaged fresh-cut vegetables, though the results vary depending on the type of vegetables and the storage temperature.

Important human pathogen associated with fresh-cut produce because it is common in the natural environment of fruits and vegetables, the pathogen is psychrotrophic from nature (minimal temperature for growth is between 0 and 4°C), the minimal pH is 4.5 to 5 (ICMSF 1996), and it is unaffected by the modified atmospheres used for fresh-cut vegetables and fruits (Berrang et al. 1989a; Beuchat and Brackett 1990 The content of the food may have an influence, since carrots have an antilisterial effect.

Initially, attention was focused primarily on anaerobic pathogens, particularly proteolytic Clostridium botulinum, which produces a lethal heat-unstable toxin but does not grow below 10°C, though nonproteolytic types B, E, and F have been recorded as growing and producing toxins at temperatures as low as 3.3°C (Francis et al. 1999).

Aerobic spoilage microorganisms rapidly reduces the redox potential of the food, enhancing conditions for C. botulinum development.These findings prompted the FDA to propose that packing sheets used for high respiring mushrooms be punctured (Doyle 1990). Growth to higher numbers (105 to 106 CFU/g) and toxin production are required before there is a significant threat to food safety. The natural microflora found in fresh-cut fruits and vegetables mostly inhibits its development. Moreover, toxin synthesis is discouraged under these circumstances. Yet, because these spores are abundant in soil, they are frequently separated from plant materials.

Virus

Another type of microbe that may provide a health risk to fresh-cut vegetables and fruits is enteric viruses. Foodborne viruses are classed based on the disease they produce: viruses that cause gastroenteritis, such as noroviruses, and viruses that cause hepatitis, such as hepatitis A virus.They are distinguished by a low infectious dosage and a high quantity of viruses in faeces (Carter 2005). Since enteric viruses are obligate intracellular parasites, unlike bacterial pathogens, they cannot develop on meals. Survival on fruits, vegetables, and soil has been documented. Badawy et al. (1985) investigated rotavirus survival on lettuce, radishes, and carrots held at 4°C and room temperature. The virus could persist at 4°C for 25 to 30 days and at room temperature for 5 to 25 days. The lettuce provided the best chance of survival. Kurdziel et al. saw no drop in poliovirus after 2 weeks of strawberry preservation (2001). After 7 days at 4°C, MS2 coliphage was reduced by less than 1 log on many crop kinds such as lettuce, cabbage, and carrots (Dawson et al. 2005). Similarly, no decrease in HAV was seen in lettuce that had been refrigerated for 9 days. Even at low temperatures (3 to 10°C), poliovirus and Coxsackie virus survived for at least 90 days in soils. This might be long enough to taint summer vegetables.Preharvest, harvest, and postharvest viral contamination are all conceivable. Enteric viruses can be introduced to fresh produce by preharvest applications such as the use of faecal contaminated sewage or irrigation water on the field. Several types of food, such as raspberries and strawberries, cannot be harvested mechanically. The perishable berries must be picked by hand, which provides an extra risk if fruit pickers do not exercise appropriate hygiene. There have also been outbreaks of viral gastroenteritis in which food workers were ill after preparing or serving involved meals.

Fresh-Cut Fruits and Vegetables: Microbiological and Safety Considerations

Parasites

Giardia duodenalis (also known as Giardia intestinalis or Giardia lamblia), Cryptosporidium parvum, and Cyclospora cayetanensis are the most common parasite protozoa that cause intestinal illnesses in the food business. Tissue protozoa Toxoplasma gondii, which causes foetal abnormalities, may also cause food and waterborne toxoplasmosis (Dawson 2005). This category of foodborne pathogens has received little attention in affluent nations, despite the fact that the problem is becoming more serious (Rose and Slifco 1999). A survey conducted in Norway between August 1999 and January 2001 found Cryptosporidium or Giardia in many plants. The most significant tainted product was mung bean sprouts, although lettuce, dill, radish sprouts, and strawberries were all shown to be affected (Robertson and Gjerde 2001). The major causes of the observed rise include an increase in the number of vulnerable people, increased cross-border traffic in produce, advancements in foodprocessing technology, and changes in national and international food safety legislation. Parasite detection from fruits and vegetables is often insufficient, with low and variable recovery efficiency. Robertson and Gjerde, on the other hand, provided novel methods for isolating and counting parasites from fruits and vegetables. Survival research is limited and mostly focuses on aquatic conditions (Erickson and Ortega 2006). C. parvum oocysts inoculated on iceberg lettuce were shown to be 90% inactivated after three days at 4°C, but 100% inactivated after three days at 22°C. Survival was higher on textured leaves than on smoother leaves.Contamination vehicles include sewage effluent, surface water, and polluted irrigation water. G. lamblia and C. parvum are assumed to be transferred by both animal and human sewage, but C. cayentanensis is thought to be transmitted solely by human sewage. In addition to water, the food handler may be a major source of protozoan parasite infection of fresh produce while harvesting or handling fresh fruit.

Developing Microbiological Standards for Pathogens Found in Fresh Fruits and Vegetables

Food safety must be ensured by a preventative strategy that includes the use of hygiene measures such as Good Agricultural Practices (GAP), Prerequisite Programs (PRPs), and Hazard Analysis Critical Control Point (HACCP) at various levels of the supply chain. To increase the microbiological safety of fresh-cut fruits and vegetables, the agriculture sector, food business, and distribution network must collaborate. Microbial sample can be used to validate the food chain; consequently, criteria must be supplied. Microbiological criteria are commonly utilised in the food industry, although they are rarely publicised (Stannard 1997) since they are mostly internal criteria employed by food business owners. Nonetheless, the adoption of EU Regulation 2073/2005 on microbiological standards for products marks a significant advancement for 70 Innovations in Fresh-Cut Fruits and Vegetables. Processing the safety of fresh-cut vegetables and fruits since standards for *L. monocytogenes* as a food safety criterion as well as Salmonella spp. and E. coli as process hygiene criteria are now included in Europe. Fresh, uncut, and unprocessed vegetables and fruits, excluding sprouted seeds, are regarded ready-to-eat items, however routine testing for *L. monocytogenes*, as indicated in this rule, is not beneficial in typical situations. Nevertheless, because *L. monocytogenes* may be found on raw materials entering the fresh-cut food industry, it is recommended that specific raw materials be tested for *L. monocytogenes*.

Fresh-cut fruits and vegetables must be classified "ready-to-eat items able to support development of *L. monocytogenes*," where the food safety standards are defined as maximum 100 CFU/g at the end of the shelf life, indicating that a maximum of 100 CFU/g may not be exceeded for the whole shelf life.Nevertheless, depending on the shelf life of the fresh-cut veggies (less than 5 days) and the pH of the produce (pH less than 4.4, which will be the case for the majority of fruits), they can also be termed "ready-to-eat items unable to sustain *L. monocytogenes* development." When growth on a food product is conceivable, the objective or target value should be absent in 25 g on the day of manufacture, and a tolerance value can be established as long as the maximum of 100 CFU/g at the end of the shelf life is not surpassed. It is the responsibility of the food service operator to study how *L. monocytogenes* will behave during shelf life. The tolerance value on the day of production can be changed in proportion to the potential of *L. monocytogenes* to develop in the concerned food product under the required storage circumstances within the stipulated shelf-life term. Its expansion can be assessed (for example, by challenge testing in which the pathogen is intentionally inoculated on the product), through scientific literature, or through predictive modelling. If the food company operator cannot demonstrate this growth, the tolerance threshold of absent in 25 g should be utilised.

The conduct of a challenge test is recommended, in which the pathogen's growth or survival in a specific product is assessed in order to determine product standards on the day of production (Norrung et al. 1999; Norrung 2000). Group 1—fresh-cut fruits and vegetables, where growth during shelf life can be expected and can pose a risk to public health by exceeding the criteria of 100 CFU/g (e.g., 2 log growth during 7 days of shelf life for MA packaged fresh-cut produce at 7°C); group 2—fresh-cut fruits and vegetables, where growth during shelf life can be expected but is limited (e.g., 1 log growth during 7 days of shelf life for MA packaged fresh-cut produce at 7°C).Non-European-Community nations frequently have a different perspective on *L. monocytogenes*: for example, the United States and Canada implemented a zero tolerance for specific goods (absence of *L. monocytogenes* in 25 g), particularly items that promote growth and have long shelf lives. Decontamination procedures are frequently permitted in the manufacturing chain in these nations in order to lower bacterial load and avoid the presence of diseases. A Microbiological and Safety Aspects of Fresh-Cut Fruits and Vegetables 71 review of the microbiological requirements for *L. monocytogenes* on fresh-cut vegetables and fruits, according to European law 2073/2005, is provided. In terms of other pathogens, the absence of Salmonella in 25 g is generally recommended for fresh-cut produce in France, the United Kingdom, the United States, and Germany (Francis et al. 1999), and is followed in the European regulation regarding food safety criteria (EU Regulation 2073/2005), but is defined as a variety of microorganisms can be evaluated as hygiene indicators in food production. The presence of a hygiene indicator over a given threshold implies an insufficiently sanitary manufacturing process in general, and maybe faecal contamination in particular. The presence of E. coli also suggests the existence of ecologically related diseases (e.g., Shigella, Salmonella). Escherichia coli is a real indication of faecal origin, and its presence indicates the existence of additional faecal infections (taxonomically, ecologically, and physiologically). E. coli can be utilised as a hygiene indication both throughout the manufacturing process and during storage. E. coli is employed as a hygiene indicator for fresh-cut vegetables and fruits under EU Regulation 2073/2005.

Staphylococcus aureus is another common hygiene indicator used to indicate personal hygiene. It is a common bacteria found on the hands, as well as in the mouth and nose. S. aureus is also a food intoxicant, but only at high concentrations (105 to 106 CFU/g). Low numbers are tolerable (Table 3.5). Because this bacteria cannot grow at temperatures below 10°C and its development on raw materials is hampered by competition with a big accompanying flora, high numbers can never be obtained when the cold chain is maintained. Extreme readings suggest either temperature abuse or a localised significant postcontamination as a result of personnel handling.

Determination of the Shelf Life of Fresh Cut Fruits and Vegetables: Combining Spoilage and Safety Aspects

Each food processor is responsible for determining the shelf-life of goods before they are placed on the market. This shelf-life date will be very short for fresh-cut fruits and vegetables, hence a "best before" date with an indication of the day, month, and, preferably, year should be given on each package. Several features of fresh-cut fruits and vegetables must be considered in order to calculate an accurate shelf-life date. Fresh-cut vegetables and fruits, as previously noted, are susceptible to both physiological (metabolic) and microbiological deterioration. When physiological activity is allowed to continue, spoiling occurs, affecting its sensory qualities (e.g., discoloration, enzymatic browning). Moreover, degradation might occur in the case of substantial development of spoilage bacteria, leading in a decrease in sensory quality (e.g., off odour and off flavor, loss of texture). Food safety must also be taken into account: fresh-cut fruits and vegetables on the market may not be dangerous to customers. As a result, while determining the shelf-life date of fresh-cut fruits and vegetables, food safety (and potential pathogen development) and food quality (microbiological and physiological degradation) should be taken into account and analysed. Interactions between these should be explored during the shelf-life research because, unlike other food items, fresh-cut vegetables and fruits are still living tissues with a distinct metabolism. The right parameters that will be followed and assessed throughout the shelf-life tests must be chosen with care.

There are various reasons why fresh-cut vegetables is less dangerous than other foods. Most pathogens cannot develop in the conditions used with fresh food (refrigeration temperatures, relatively limited nutrients available in some types of vegetables, e.g., leafy vegetables, low pH of fruits, short shelf life). Most spoilage bacteria in chilled produce are psychrotrophic, giving them an edge over most diseases.This rivalry can sometimes impede pathogen development. In certain circumstances, the food just spoils before being consumed. Nonetheless, foodborne disease can and does occur with the consumption of fruits and vegetables, particularly when fresh-cut produce is packaged in modified atmosphere packaging, which increases the shelf life of the products and allows pathogens more time to develop to infectious numbers before the product is noticeably spoiled. Temperature abuse should be addressed while conducting shelf-life experiments. Most European nations keep these items between 4 and 8°C; higher temperatures cause physiological deterioration and allow microbes to grow more quickly. After microbiological sampling, four to six participants of a trained sensory panel assessed the fresh-cut vegetables for visual and organoleptic qualities.

In general, sensory qualities restricted shelf life quicker than microbiological criteria if proposed an image limited shelf life. When compared to air-stored veggies, the shelf life of vegetables stored under MA was increased by 40% or more.In a second storage experiment, the four fresh-cut vegetables were injected with a mixture of *Listeria monocytogenes* psychrotrophic strains before being packaged under MA and air at 7°C. The kind of vegetable had a greater impact on pathogen growth than the type of environment. There was no growth on Brussels sprouts, while carrots' antilisterial component stopped Listeria from developing on this item (see Table 3.6). Fresh-cut veggies packed under an EMA (2% to 3% O_2, 2% to 3% CO_2, 94% to 96% N_2) had a good influence on their sensory characteristics.

By keeping the veggies in a lower oxygen environment (5% O_2), enzymatic discoloration is reduced and the rigid structure is retained for longer by slowing the respiration rate/transpiration losses. The EMA's impact on microbiological quality was not always clear. The favourable impact of EMA storage on vegetables is due to the physiological status of the product rather than the suppression of soft-rot bacteria.Nevertheless, for rotting microorganisms on shredded chicory endives and iceberg lettuce, an extension of the lag period might be proposed. The expansion of spoiling microorganisms reached the same level as the microbiological counts for the air-stored vegetables at 7°C as the sensory quality of the packed vegetables dropped. The sensory qualities of the EMA and the air-stored product reduced the shelf life quicker than the microbiological requirements. Grated carrots were an exception: These circumstances promoted lactic acid bacteria development.

Psychrotrophic pathogens, such as *L. monocytogenes*, could develop in an EMA at 7°C and were impacted more by the kind of vegetable than by the type of environment. Based on the shelf life determination, safety standards for *Listeria monocytogenes* may be specified on the day of production: absence in 0.1 g for shredded iceberg lettuce and shredded chicory endives. Absence in 0.01 g on the day of production for grated carrots and trimmed Brussels sprouts might be attributed to the fact that *L. monocytogenes* did not thrive on these fresh-cut veggies.

CHAPTER 5

PHYSIOLOGY OF FRESH-CUT FRUITS AND VEGETABLES

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The concept of preprocessing fruits and veggies in their fresh form began with fresh-cut salads and has now evolved to fresh-cut fruits and vegetables. Freshcut food comprises fruits, vegetables, sprouts, mushrooms, and even herbs that have been cut, cored, sliced, peeled, diced, or shredded but have not been cooked or changed in any way from their fresh form. Physiologically, this involves hurting living tissue, which initiates a chain reaction of metabolic responses that can cause textural changes, rapid ripening and senescence, off tastes, discoloration, and other undesired occurrences that can leave the product unmarketable.In terms of microbiology, removing the protective peel of fresh produce results in a sliced surface that is awash with cell contents, making the surface appealing to plant diseases. Increased ethylene, a gaseous ripening plant hormone, arises from the additional handling and processing of the product, which results in genetic signals that encourage ripening and senescence.

88 Fresh-Cut Fruits and Vegetables Advances Handling and processing also increase the rate of respiration, depleting sugar and acid substrates and lowering shelf life. Lastly, the additional handling, peel removal, and alteration of the typical microbial ecology of fresh-cut goods allow for the contamination and proliferation of human diseases. Many processing techniques have been developed to counteract the reactions of the cut produce to ethylene production and other wound responses, including the use of precooling to reduce respiration; prequality assessment for microbial stability, modified atmosphere packaging (MAP), and other packaging to reduce respiration and ethylene production. As previously said, all of the above have been the subject of several evaluations. Some broad evaluations for prolonging the shelf life and quality of fresh-cut food are Ahvenainen, Shewfelt, Soliva-Fortuny and Martn-Belloso, and Watada and Qi (2006). (1999).

The consequences of processing fresh produce into fresh-cut products have also been examined, including the effect on general quality, warnings, physiology, flavour (Forney, 2008), browning, physiological (Huxsoll and Bolin, 1989). In general, fresh-cut fruit deteriorates considerably faster than entire fruit. In a research comparing fresh-cut fruit against intact fruit, the fruit was kept at 5oC for up to 9 days.Only fresh-cut watermelon and mango pieces were still marketable at the end of the storage time of the fruit examined (pineapples, mangoes, cantaloupes, watermelons, strawberries, and kiwifruits). The loss of vitamin C and carotenoids in some of the chopped fruit items was 5 to 25% and 10 to 25%, respectively, but minimal in the whole fruit. Conversely, there were no differences in vitamin C, flavonoids, or colour for intact vs fresh-cut spinach after 1 week at 4oC (Bottino et al., 2009), indicating that the effect of little processing varies on the commodity.

In light of the numerous evaluations on fresh-cut goods that have been published to date, this chapter will outline the literature on fresh-cut physiology that has been published in the last 5 years or so. Substantial research relating to quality and microbiological stability continues to be published in this field, however food safety will not be discussed here unless in situations where there are reports of consequences on fresh-cut produce physiology. Wounding causes physiological changes that effect quality and spoilage; hence, this chapter may overlap with previous topics but will focus on the physiological reasons and metabolic mechanisms that produce quality and microbiological concerns. Plant wound reactions are classified as follows: increased ethylene production, increased respiration, increased secondary metabolite production, rapid ripening and senescence, cut surface discoloration, texture alterations, and off-flavors. To comprehend the physiology of fresh-cut produce, some fundamental plant physiological information is provided first, focusing on ripening wounding ethylene, and respiration.

Stress and Wounding in Plants

Damaged or stressed plants release signals that activate a wide variety of genes, the results of which are intended to aid in plant healing, defence against pathogens, or indicate cell death to prevent infection (Dangl and Jones, 2001; Kessler and Baldwin, 2002). Oligogalacturonides (OGAs) (Via et al., 2007), which are derived from the cell wall; jasmonic acid (JA) and methyl jasmonate (MeJA) (Howe, 2004), which are derived from membranes (plastids, linolenic acid) via lipoxygenase (13-LOX); salicylic acid and methyl salicylate (wintergreen) derived from benzoic Other signals, such as the protein systemin, OGAs, ethylene, and other elicitors, modulate the wound-induced JA pathway (Howe, 2004; Ryan and Moura, 2002). These signals are considered to be sent to a lipase, which causes linolenic and linoleic acid to be released from membrane lipids. A full-length cDNA clone expressing Capsicum annum GDSL-lipase 1 (CaGL1) expression was induced, for example, by MeJA and wound stress (Kim et al., 2008b). Pathogenesis-related (PR) proteins and proteinase inhibitors are also produced in response to these signals (Fallico et al., 1996). Ethylene has been found to be a wound-mediating signal.

Because fresh-cut fruits and vegetables are injured tissue, all of the following might occur. Cell walls and membranes were shown to have a role in the quick degradation of fresh-cut papaya, resulting in softening, pectin breakdown, enhanced polygalacturonase (PG, releases OGAs), -and -galactosidase, lipoxygenase, and phospholipase D activities (release linolenic and linoleic acids). They are more likely to generate wound signs. They then investigated the signalling and expression of wound-regulated cDNAs in fresh-cut papaya vs undamaged fruit (Karakurt and Huber, 2007). The cDNAs had similarities with genes involved in signaling pathways, membrane proteins, cell-wall enzymes, proteases, ethylene biosynthetic enzymes, and enzymes implicated in plant defence responses.Abiotic stressors and wounds can also boost antioxidant phytochemical levels. Antioxidants scavenge reactive oxygen species (ROS) that can harm plant cells, are produced as byproducts of normal metabolism, and are involved in the signalling and function of antioxidant systems to detoxify ROS.

ROS may act as signal messengers after wounding (Orozco-Cardenas et al., 2001) and are involved in the production of lignin and suberin during wound healing (Reyes et al., 2007). Phenolic chemicals in fruits and vegetables have higher antioxidant activity (Mahattanatawee et al., 2006), and their accumulation may have health advantages. Yet, in the case of sliced apple, the cutFresh-Cut Fruits and Vegetables Physiology Surface browning caused by phenolic compound production triggered by cutting is regarded undesirable and can be prevented by surface treatments discussed later in this chapter. Yet, the stress of cutting may result in higher antioxidant levels in some fresh-cut items, which may translate into health advantages.

The way fruit is sliced might cause more or less wound reactions, which influences shelf life. In general, increasing cutting increases respiration rates (wounding). In a research on carrot processing settings, the respiration rate was highest for shredded carrots (75 mL O2/kg h) and lowest for whole carrots (26 mL O2/kg h). Several cut kinds of fresh-cut papaya fruit had various physiochemical and microbiological qualities. As compared to papaya cubes, papaya spheres showed less colour change, hardness loss, and higher titratable acidity, retention of soluble solids and less weight loss, higher vitamin C content, and lower microbial counts (Argaosa et al., 2008). Fresh-cut lemons, wedges, slices, and half and quarter slices were investigated at various temperatures. The sensory properties of the quarter slice were not as well preserved as those of the bigger slices.

Ethylene Manufacturing

In low concentrations (parts per billion to parts per million), ethylene is a gaseous plant hormone that is physiologically active. Ethylene production occurs at some degree in all plant tissues. It stimulates seed germination, degreening, adventitious root production, abscission, ripening, and senescence (Baldwin, 2004; Reid, 1985). It is required for growth (typically thickening or lateral growth, as with etiolated pea seedlings). When ethylene encourages its own synthesis, it is termed autocatalytic, and when it inhibits ongoing production, it is considered autoinhibitory. System-1 ethylene is assumed to be autoinhibitory during vegetative development, but system-II ethylene is expected to be autocatalytic during climacteric fruit ripening and floral senescence. Each appears to be governed in a distinct manner. System-II ethylene promotes softening, colour changes, and browning by inducing activity of PG, cellulase, chlorophyllase, polyphenyloxidase (PPO), peroxidase (POD), and phenylalanine ammonia-lyase (PAL) (Kader, 1985; Watada, 1986). Ethylene causes fruit to ripen (Koning, 1994). Commercially, it is used to ripen fruits like as bananas, mangoes, melons, and tomatoes (100 to 1,000 L/L) and to degree citrus (Watada, 1986). Ethanol production rates are often higher when linked with meristematic, stressed, or ripening tissues. For example, ethylene production is highest in immature fruit or tissues during fast cell division, then decreases during cell expansion and then increases again during ripening (fruits) or senescence (flowers). In reaction to ethylene, climatic fruit can ripen off the mother plant (Baldwin, 2004). They can respond to either their own ethylene production (which becomes autocatalytic), exogenously supplied ethylene, or both.

In many fruits and vegetables, ethylene is linked to colour and taste development as well as softening (Kader, 1985; Watada, 1986). Ethylene is also generated at high levels in reaction to plant stress or injury, which happens with fresh-cut goods. This high ethylene, which can be caused by ripening for climacteric fruit or wounding for both climacteric and nonclimacteric fruit, might be active in fresh-cut items. Several ripening, stress, and wound responses are triggered by ethylene through signalling and subsequent gene expression (Bailey et al., 2005). As previously stated, they include the creation of browning enzymes, secondary metabolites, chlorophyllase, cell wall degrading enzymes, secondary metabolites, lignin, and more ethylene (if autocatalytic), or a decrease in ethylene synthesis (if autoinhibitory). This can cause broccoli florets to yellow, fruit tissue to soften, cabbage leaves to abscise, lettuce to pink and brown, sliced apple to brown, potato to sprout, asparagus stems to toughen, and carrots to taste bitter (isocoumarin). Ethylene induces colour changes, softening, and general ripening and senescence in intact fruit. Ethylene increases discolouration, off-flavor, softening, ripening, and senescence in fresh-cut fruit. In general, ethylene reduces the shelf life of whole or fresh-cut items. Several methods for extending the shelf life of undamaged or fresh-cut vegetables involve blocking or delaying ripening and wound response ethylene generation or effect.

Ethylene is thought to be synthesised from the amino acid L-methionine, which is converted to S-adenosylmethionine (SAM or adomet) by the enzyme methionine S-adenosyltransferase, which is converted to 1-aminocyclopropane-1-carboxylic acid (ACC) by ACC synthase (ACS), which is converted to ethylene by ethyleneforming enzyme (Figure 4.1). The pathway's major regulatory enzymes are ACS and ACO. Ripening affects both ACS and ACO; however, wounding and water stress only affect ACS.

1-MCP inhibits ACS and ACO, whereas aminoethoxyvinylglycine (AVG) and aminooxyacetic acid (AOA) only inhibit ACS, and high temperature (>35°C) and anaerobiosis only inhibit ACO. Malonyltransferase is an enzyme that can catalyse the conjugation of ACC into malonyl ACC (Fallico et al., 1996). Ethylene has the ability to switch on or off genes that encode a component of its biosynthesis process (autocatalytic or autoinhibitory, respectively).

It is typically autoinhibitory in vegetative and juvenile reproductive tissues and autocatalytic in mature reproductive tissues such as flowers and fruit, as previously stated (Baldwin, 2004; Lelièvre et al., 1997; Saltveit, 1999). As a result, fresh-cut goods may react differently depending on whether they are made from vegetative, reproductive, climacteric, or nonclimacteric tissue.

ACS, the rate-limiting step in ethylene biosynthesis, is encoded by a complex multigene family (Zarembinski and Theologis, 1994). Ethylene can enhance malonyltransferase levels in numerous tissues, which may explain for the autoinhibition that is occasionally observed (Vangronsveld et al., 1988). The synthesis of ethylene requires O2 and is suppressed by high amounts of CO2, particularly when the reaction is autocatalytic, as in climacteric fruits (Abeles et al., 1992; Sisler and Wood, 1988).As a result, MAP is used with fresh-cut items to limit ethylene and respiration, extending shelf life. Wound-response ethylene is considered to boost ACS activity (Apelbaum and Yang, 1981; Boller and Kende, 1980). Ethylene must bind to a receptor, which is considered to be located in a membrane, in order to have a biological impact.

If the receptor is inhibited, ethylene has no impact (inhibition of ethylene action).Silver ions, CO_2, 2,5-norbonradiene, and 1-MCP may all inhibit ethylene-induced effects, including its own synthesis in circumstances where ethylene is autocatalytic, or enhance its synthesis in cases where ethylene is autoinhibitory (Abeles et al., 1992; Saltveit, 1999; Sisler et al., 1986). Only 1-MCP is food-safe and has thus been utilised to limit ethylene reactions and production in fresh-cut items.

The suppression of the ethylene transporter (LeETR4) caused early tomato ripening but had no effect on fruit size, yield, or taste composition, indicating that ethylene receptors may operate as biological clocks that govern the commencement of fruit ripening. Ethylene receptors are destroyed in the presence of ethylene, most likely via a proteasome-dependent process; hence, immature fruits exposed to ethylene have less receptor protein and ripen quicker (Kevany et al., 2007). In other words, the receptor works as a negative regulator of ethylene responses, and when ethylene attaches to the receptor, the suppression is abolished. Figure 4.2 (Ecker, 2004; Li and Guo, 2007; Schweighofer and Meskiene, 2008) illustrates that plant cells initiate protein phosphorylation cascades regulated by kinases after wounding or other stress sensing. MAP kinases, such as MKK4, MKK5, and MPK6, phosphorylate target proteins, causing cell responses. ACC synthase, the enzyme responsible for ethylene synthesis, is one of the targets (ACS). Members of the ACS family's two main subgroups, represented by ACS5 and ACS6, are controlled by distinct kinase pathways.Phosphorylation stabilises ACS6 (and perhaps ACS5), and ACS5 interaction with unknown components directs ACS5 for proteasome destruction. Fine-tuning

Tissue-specific expression, gene activation, and the synthesis of heterodimers between various ACS members all contribute to ethylene induction. The activity of ACC oxidase (ACO) can also influence ethylene induction levels. Ethylene binding inactivates ER-localized receptors (ETR1, ETR2, ERS1, ERS2, and EIN4) by an unclear mechanism. RTE1, a new membrane protein, may particularly improve the activity of the ETR1 receptor. An inactive receptor is unable to attract the negative regulator CTR1 to the ER membrane, hence inhibiting its function.EIN2 is thus free of CTR1 inhibition and enhances EIN3 protein nuclear accumulation by inhibiting turnover, which is mediated by SCF complexes including the F-box proteins EBF1/2. There are two ways in which EIN2 can stabilise EIN3: EIN2-derived signal either directly controls EIN3 or inhibits the SCFEBF complex. EBF2 is one of the EBF genes that is activated by ethylene in an EIN3-dependent way. As a result, a negative feedback loop forms between EIN3 and EBF. EIN5, an exoribonuclease, appears to suppress the expression of EBF1 and EBF2 mRNAs without changing their half-life. EIN3 nuclear accumulation produces a considerable quantity of gene expression and, as a result, numerous ethylene responses.

As a result, inhibiting or reducing ethylene production or activity can assist to increase the shelf life of fresh-cut items, albeit this will vary depending on the kind of product (vegetative, reproductive, harvest maturity, etc.). There are a variety of ways for reducing ethylene production or effects that may be applied to the intact fruit prior to processing or straight to the processed product. Genetics (Klee and Clark, 2002), storage temperature, MAP packaging, coatings, ethanol, ethylene absorbents, and 1-MCP are examples of such treatments. Preharvest, ethylene synthesis inhibitors such as AVG can be used to prevent ethylene production, which can alter postharvest shelf life. Genetic engineering can also be utilised to minimise fruit ethylene production, as demonstrated in tomato by downregulating ACS , ACO, or increasing ACC deaminase expression. Antisense molecular approaches have also been employed to wipe off the ethylene receptor, rendering the tissue nonresponsive to ethylene. Tomatoes with downregulated ACS or ACO, for example, generate little ethylene and do not ripen, while tomatoes with inserted ACC deaminase produce little ethylene as well, because this enzyme degrades ACC to -ketobutyric acid. These transgenic fruits, if authorised, might be valuable as fresh-cut items.

Temperatures exceeding 35oC can harm the ethylene biosynthetic pathway, causing ethylene production to be disrupted. Because of lower ACO activity, cold temperatures below 2.5oC impede metabolism, including ethylene production (Wang and Adams, 1982). Because the ethylene biosynthetic route requires O2 and is blocked by CO2, the comparatively low oxygen (O2) and high carbon dioxide (CO2) levels in MAP or the internal environment of coated fruit (Bai et al., 2001; Bai et al., 2002) restrict ethylene synthesis. ACO is inhibited by anaerobic environments. Ethanol has been shown to inhibit ethylene production in intact tomato fruits (, and ethanol vapour has been used to inhibit ethylene production in cut apple and mango fruits. (Bai et al., 2004; Plotto et al., 2006). Ethanol vapour treatment can be troublesome since it can generate changed or off-flavors, although only at low levels.96 Fresh-Cut Fruits and Vegetables Advances The ethanol treatment of intact mango fruit has the extra benefit of lowering the microbial population on the surface of the sliced mango.

1-MCP, an ethylene action inhibitor, similarly decreased ethylene effects in cut fruit by blocking ethylene action (Bai et al., 2004; Ergun et al., 2007; Perera et al., 2003; Saftner et al., 2007). This includes, in certain circumstances, autocatalytic ethylene production (Baldwin, 2004). Treatment of intact apple with 1-MCP decreased ethylene production, respiration for 'Braeburn,' 'Pacific Rose,' and 'Gala' subsequent sliced products, and browning for 'Braeburn' cut apple. Treatment of intact fruit resulted in less softening and watersoaking of subsequent fresh-cut fruit for 'Galia' melon. In conjunction with MAP, treatment of intact pineapple resulted in reduction of respiration and ethylene generation, as well as delayed softening (Rocculi et al., 2009). Kim et al. (2007) found that fresh chopped cilantro lowered respiration. Low dosing 1-MCP treatments applied to intact watermelon prior to ethylene exposure reduced ethylene-mediated quality decline in subsequent fresh-cut slices under MAP (Saftner et al., 2007). The use of 1-MCP before or after kiwifruit processing decreased ethylene and softening, which was aided by a calcium chloride dip (CaCl2). When applied directly to fresh-cut mango slices, 1-MCP minimised softening and browning. Direct administration of 1-MCP after processing resulted in greater ethylene synthesis, delayed softening, and colour darkening with no impact on respiration in fresh-cut persimmons.

Respiration

Fruit ripening, senescence, and wound healing are all energy-intensive processes. A fruit or vegetable's respiratory quotient is the ratio of CO2 generated to O2 consumed. In fresh produce, novel proteins, messenger ribonucleic acids (mRNAs), pigments, and taste compounds are created, which requires energy and carbon from the fruit, as with other tissues. Yet, once harvested, the fruit has limited resources, which is especially noticeable in fresh-cut items. When stored below 5oC, fresh-cut lemons had two to five times the respiration of whole lemons and a 12-fold greater respiration when stored at 10oC. Ripening of climacteric fruit and injury of all fruit result in a distinct increase in respiratory activity. In general, the higher the respiratory rate, the shorter the shelf life, since respiratory substrates, which are mostly sugars and acids, are consumed (Tucker, 1983). Fruit sugars and acids are often sequestered in the vacuole but are occasionally released or retained in a separate pool for use in respiration (Tucker, 1983; Tucker and Grierson, 1987). The glycolysis, oxidative pentose phosphate (OPP) route (less significant, but may work in climacteric respiration), and tricarboxylic acid (TCA) pathways are the respiratory mechanisms used by fruit to oxidise carbohydrates. Glucose-6-phosphate (P) is transformed to fructose 6-P, which is turned to fructose-1, 6-bisphosphate, and phosphoenol pyruvate to pyruvate during glycolysis. Pyruvate contributes to the TCA cycle. Malic acid appears to be utilised as a respiratory substrate by malic enzyme, which decarboxylates malate to pyruvate, with the excess carbon being given into the TCA cycle, whereas citrate can feed straight into the TCA cycle (Goodenough et al., 1985; Tucker, 1993). Plant mitochondria oxidise the NAD(P)H generated by glycolysis, TCA, or malic enzyme activity, and the energy is utilised for adenosine triphosphate (ATP) production via oxidative phosphorylation, which is mediated by membrane-bound dehydrogenases in the mitochondria (Palmer and Moller, 1982; Tucker, 1993).The ancient eukaryotic cell obtained several metabolic capacities by the engulfment of a -proteobacterium, the mitochondrion.

The mitochondrion is especially sensitive to cellular ATP needs. The mitochondria also creates ROS, which, as previously stated, are powerful intracellular signals for abiotic stress and oxidative protein damage, acting as an early warning sensor of disturbed cellular redox equilibrium. ROS are produced in the mitochondrion when the respiratory complexes are overreduced, resulting in electron leakage to molecular oxygen and superoxide production (Moller, 2001). This is caused by an imbalance between electrons entering the respiratory chain and the dissipation of the proton gradient by ATP synthesis, or by electron transport processes caused by a change in physiological state (low temperature) (Sweetlove et al., 2007) or injury, as with fresh-cut produce. What matters is the balance between ROS generation and antioxidant capability. The alternative oxidase (AOX) reacts to redox signals, bypassing most of the respiratory chain and reducing proton pumping and ROS generation considerably. The TCA cycle is connected to AOX expression, and TCA cycle intermediates may function as signals for gene expression.In terms of the relationship between climacteric ethylene and respiration, it appears that a developmental component is involved in the activation of the respiratory climacteric.Honeydew melon, for example, must reach a particular maturity level before low doses of exogenous ethylene can increase climacteric ethylene and respiration. In a study comparing antisense ACO cantaloupe harvested 20 to 35 days after pollination to wild-type fruit, it seemed that developmental variables and ethylene levels interacted in the activation of the respiratory upsurge.

Storage Temperature and Atmosphere Modification

The Environment

The temperature at which fresh-cut commodities are stored impacts their respiration rate, which rises as the temperature rises. This impact is amplified if the commodity is stored in a modified environment (MAP packaging, coating, or CA storage) with relatively low O_2 and high CO_2, which is most likely meant for low-temperature (therefore, low respiration) storage. If the cold chain fails, the respiration rate/O_2 demand rises, and the O_2 level may fall below the extinction point for that commodity, triggering the anaerobic pathway, which produces ethanol and off-flavors. Sometimes a product has an okay look but a poor flavour.The product will thereafter soon degrade. When the temperature was raised from 0 to 10oC, the Q10 of respiration rates of fresh-cut vegetables ranged from 2 to 7.5.

98 Innovations in the Processing of Fresh-Cut Fruits and Vegetables (Watada et al., 1996). High O2 MAP (70% + O2) has also been used to prevent anaerobic fermentation and to restrict aerobic and anaerobic bacteria growth. It has also been demonstrated that argon and nitrous gas diminish respiration rates.

Temperature of Storage

The temperature at which items are stored can also impact their nutritional shelf life. Temperature altered the anthocyanins and vitamin C content as well as the antioxidant capacity of the cut strawberry held 21 days under 80% O2, which decreased wounding stress in a study of the antioxidant potential of fresh-cut strawberries (Odriozola-Serrano et al., 2009). Vitamin C degradation was more sensitive to modest temperature changes than the other antioxidant components, and a storage temperature of 5oC proved most beneficial in preserving the antioxidant characteristics of sliced strawberries under high O_2 conditions. Lycopene, vitamin C, and phenolic contents, as well as other physiochemical parameters, were maintained at 5oC in MAP (5% O2 + 5% CO2) for 14 days for fresh-cut tomato. Increasing the storage temperature increased lycopene and total phenolics while decreasing vitamin C and decreasing shelf life due to microbial development at storage temperatures over 10oC. (OdriozolaSerrano et al., 2008). One advantage of fresh-cut produce from cold-sensitive fruits is that the cut product does not always show indications of chilling injury, which is common in the intact fruit peel.

Films for fresh-cut produce frequently lack sufficient O_2 and CO_2 transmission rates to attain steady-state gas concentrations before reaching too low or too high O_2 and CO_2 levels, respectively (Oms-Oliu et al., 2007). This encourages anaerobic respiration or CO_2 damage, which causes fermentive off-flavor and odour, excess CO_2 generation, and visual flaws. The average headspace in a sample of bagged salads from major grocery chains was 1.2% O_2 and 12% CO_2, with a mean ethanol concentration of 700 parts per million (ppm) (Hagenmaier and Baker, 1998). Fresh-cut sweet potato placed in medium- or high-permeability film bags at 2 or 8oC caused anaerobiosis at 2oC and especially 8oC for the low-permeability bags and 8oC for the medium-permeability bags (Erturk and Picha, 2008). However, MA is employed to minimise fresh-cut produce respiration and ethylene generation to lengthen shelf life, often in the range of 1 to 5% O_2 and 5 to 10% CO_2 (Gorny et al., 2002). This has been successfully used for kohlrabi sticks (2.5% O_2 and 9% CO_2) (Escalona et al., 2007), broccoli and cauliflower florets (1% O_2 and 21% CO_2) (Schreiner et al., 2007), minimally processed bok choy (5% O_2 and 2% CO_2) (Lu, 2007), and fresh-cut pineapple (2% O_2 and 12% CO_2) (Montero-Calderón et al. For lightly processed guava, MAP and osmotic dehydration performed well (Pereira et al., 2004). Although studies on the use of superatmospheric O_2 (>70%) to prevent anaerobic conditions were conducted, this strategy degraded the quality of fresh-cut pears by encouraging oxidative processes (reduced vitamin C, solids, and acids). The high oxygen active packages, on the other hand, lowered fermentative metabolite buildup compared to normal MAP (relatively low O_2 and high CO_2) and prevented various rotting microbes.

Fresh-Cut Fruits and Vegetables Physiology 99 (Omsâ•Oliu et al., 2007). For sliced peppers, it was discovered that 50% to 80% O_2 with less than 20% CO_2 maintained an excellent visual appearance without fermentation or off-odors.

Increased CO_2 levels aided respiration. Coating cut pears with antioxidant compounds (N-acetylcysteine and glutathione at 75% concentration) in a high O_2 (70%) atmosphere, low O_2 (2.5% O_2 and 7% CO_2 active flush), or passively modified atmosphere revealed that the low O_2 with the antioxidant treatments best maintained vitamin C, chlorogenic acid, and antioxidant capacity and reduced browning and ethylene production compared to the high O_2 treatment (Oms-Oliu et al. When compared to air, Chinese bayberry fruits treated with 80% to 100% O2 showed less deterioration, higher levels of total soluble solids, titratable acidity and ascorbic acid content, and lower pH. During storage, the high O_2 treatment was less stressful, as seen by decreased malonaldehyde level and increased catalase, ascorbic acid peroxidase, and peroxidase activity. Increased O_2 levels have been shown to boost antioxidative defence mechanisms and degradation resistance (Yang et al., 2009).

Genetics

Breeders are beginning to seek for ways to develop cultivars with fresh-cut qualities. For example, lettuce breeders are attempting to create multipurpose varieties. To that purpose, breeding lines were evaluated for enhanced cut lettuce shelf life in modified atmospheric (MA) conditions such as MAP (Hayes and Liu, 2008). Hence, genetic diversity for cut lettuce shelf life in low O_2 MA settings of 0.2% to 5% O_2 with the balance of N_2 in bags or in CA was investigated to discover whether cultivars could prevent harm from self-generated CO_2 injury or fermentation from low O_2. A unique hybrid muskmelon derived from an ultrafirm parent produced a fruit with great exterior and interior firmness, making it perfect for long-distance shipment (Lester and Saftner, 2008). This hybrid also included significant levels of sugar, -carotene, and folic acid.

Maturity of Harvest

When a product is harvested, it can alter its shelf life and quality since the fruit may or may not continue to ripen and soften after cutting. Relationships between harvest maturity and shelf life have been discovered in certain research (Chiesa et al., 2003; Couture et al., 1993; Watada and Qi, 1999), but not in others (Hayes and Liu, 2008). The length of storage period for fresh-cut cantaloupe reduced as harvest ripeness rose. Fresh-cut cubes from more mature harvested fruit (full slip) had higher vitamin C losses, and firmness losses were quicker (Beaulieu and Lea, 2007). The volatiles in more immature harvested cantaloupe (1/4 slip) were decreased (Beaulieu, 2006).

For a fresh-cut cantaloupe product, it was consequently advised to harvest at middle maturity (1/2 slip) (Beaulieu and Lea, 2007). Pear, on the other hand, is destined for 100 Fresh-Cut Fruits and Vegetables Advances Because to reduced browning potential (lower amounts of phenolic compounds in the pulp) and superior flavour (sweeter due to lower titratable acidity, higher levels of total aroma volatiles), processing for a fresh-cut product was more acceptable if collected 1 month later than regular commercial harvest (Bai et al., 2009). Later harvest ripeness resulted in increased quantities of favourable aromatic compounds in mango as well (Beaulieu and Lancaster, 2008). A fresh-cut apple produced from slightly ripe undamaged 'Fuji' apples was best suited (Rojas-Graü et al., 2007b). Yet, despite the application of an anti-browning dip, fruit picked 2 weeks or more before the commencement of climacteric ethylene production (starch index 2.5) showed higher cut edge browning (Toivonen, 2008b).

CHAPTER 6

SANITIZING TREATMENTS' PHYSIOLOGICAL EFFECTS

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Certain sanitizers have physiological impacts on the fresh-cut items that have been handled. Although $CaCl_2$ was shown to be more efficient than sodium hypochlorite (NaOCl) in reducing browning of apple and potato. When kept at 10°C, cut tomatoes treated with hydrogen peroxide (H_2O_2) had lower microbial populations; however, they also had lower phenolic and antioxidant levels after 7 days, as well as lower colour and carotenoids levels. The application of H_2O_2 on fresh-cut Chinese water chestnuts decreased surface discoloration as well as deterioration. H_2O_2 also slowed total phenolic content rises and decreased PPO, PAL, and POD activities (Peng et al., 2008; Podoski et al., 1997). Sanitation heat treatments can potentially produce heat shock and denaturation of metabolic enzymes, resulting in physiological consequences. The use of hot water to "pasteurise" the surface of cantalopes before to cutting resulted in lower microbial populations on the rind and subsequent cut melon pieces without harming the quality of the fresh-cut product (Fan et al., 2008). A modest heat treatment (45^{o}C hot water or 55^{o}C hot air for 8 or 5 minutes, respectively) followed by storage at 5^{o}C resulted in decreased O_2 consumption, ethylene generation, and deterioration.

Irradiation dosages of 0.2 to 0.8 kGy can result in a one-log decrease of bacterial pathogens, but 1 to 3 kGy is required to produce a one-log reduction of pathogenic viruses and fungi, however this can have an influence on quality. Most fresh-cut fruits and vegetables withstand doses of 1 kGy or less with minimal change in appearance, flavour, colour, or texture. In rare circumstances, there is wilting and loss of firmness due to an influence on cell membrane permeability and functioning, resulting in electrolyte leakage and tissue integrity, especially at dosages exceeding 1 kGy (Fan and Sokorai, 2008). Low-dose irradiation (1 kGy) was evaluated on 13 typical fresh-cut vegetables and found not to result in substantial losses of qualitative features (appearance, texture, taste, and nutritional content), with the exception of irradiated green and red leaf lettuce having lower vitamin C levels. Low-dose electron beam irradiation of fresh-cut cantalope reduced and stabilised respiration while decreasing microbial populations

Peach in hot water at 50oC for 10 minutes, followed by MAP storing at 5^{o}C, controlled browning and preserved firmness throughout storage, with decreased CO_2 and ethylene concentrations in the package environment (Koukounaras et al., 2008). Nevertheless, as compared to nonheated controls, heat treatment reportedly increased carotenoid loss and decreased chroma colour values on the slices, while PPO activity was unaffected.As compared to unheated controls, hot dips in $CaCl_2$ or other calcium salts (60oC) helped retain firmness (increased binding Ca levels in the cell wall), reduced microbial growth, and enhanced sensory quality (Aguayo et al., 2008).

Various calcium salts have been tested with variable degrees of effectiveness. Heat-treated sliced apple (4 days at 38^{o}C hot air) decreased ethylene production, respiration, and softening, but it also decreased fragrance volatiles. Moderate heat shock of various plant parts produced mixed outcomes, minimising browning but creating negative surface colour and texture changes.UV radiation may also be used to disinfect fresh-cut food, although it has the potential to degrade quality. Fresh-cut tomatoes produced hydroponically showed decreased microbial populations, higher phenolic content, and delayed vitamin C breakdown after 7 days of storage at 4 to 6oC. When the tomatoes were grown at reduced salt concentrations, the UV light treatment had no effect on their appearance, colour, or lycopene content.

Lycopene and vitamin C content increased in tomatoes grown at higher salt concentrations and exposed to UV treatment, most likely due to stress; however, the UV-C treatment accelerated the decline of phenolic compounds and vitamin C in the subsequent fresh-cut product of these fruit. Higher UV-C doses (up to 11.35 kJm-2) on fresh-cut spinach resulted in a loss of lightness due to superficial tissue damage and an accelerated drop in total antioxidant activity and polyphenol content after storage, despite a reduction in microbial growth (Artés-Hernández et al., 2009). UV irradiation of cut cantaloupe increased terpenoid synthesis while also causing some ester losses that were cultivar and age dependant.

Although ozonated water is used as a sanitizer, it can have physiological impacts.The use of ozonated water did not impair the shelf life of fresh-cut lettuce antioxidants, including polyphenols and vitamin C, and did not increase respiration. As compared to water and chlorine rinses, the ozone treatment reduced browning and enhanced attractiveness (Beltran et al., 2005). In a study comparing the effects of sanitising procedures such as sodium hypochlorite, electrolyzed water, and peroxyacetic acid on the respiration rates of fresh-cut vegetables maintained at 7oC with 3% O2, sodium hypochlorite enhanced the respiration of iceberg lettuce but not carrot, leek, or cabbage. Peroxyacetic acid had no effect on leek or iceberg lettuce respiration, however it did reduce carrot and cabbage respiration. Nevertheless, electrolyzed water inhibited leek and cabbage respiration peach in hot water at 50oC for 10 minutes, followed by MAP storage at 5oC, controlled browning and preserved firmness throughout storage, with decreased CO2 and ethylene concentrations in the package environment (Koukounaras et al., 2008). Nevertheless, as compared to nonheated controls, heat treatment increased total carotenoid loss and decreased chroma colour values on the slices, while PPO activity was unaffected.

Surface Treatments and Coatings

Fresh-cut fruit is frequently treated to fight physiological changes such as browning, softening, taste changes, and losses of minerals or other beneficial substances, as well as dehydration.

Surface Coatings

Browning of cut tissue is caused by the activity of PPO, with minor participation from POD and PAL in some circumstances. POD is a heme-containing enzyme that may oxidise phenolic compounds with a single electron in the presence of H_2O_2.PPO's generation of H_2O_2 when oxidising particular phenolics might result in synergistic activity between PPO and POD (He and

Luo, 2007). Ascorbic acid and its derivatives can be used as an antioxidant and acidulant to minimise browning. Citric, malic, tartaric, oxalic, and succinic acids can also be employed to acidify the surface and function as a browning chemical chelator. Calcium or its compounds can be utilised to improve firmness and decrease browning. Since PPO activity is sensitive to pH, acidifying the surface helps to suppress it. The active site of PPO isoenzymes contains two copper ions. With oxygen as a cosubstrate, this enzyme may catalyse the hydroxylation of monophenols and the oxidation of diphenols to quinones. Brown pigments are formed when quinones polymerize. Thiol-containing substances such as cysteine, glutathione, and acetylcysteine are thought to generate colourless thiolconjugated o-quinones (He and Luo, 2007). Sulfates (restricted by the US Food and Drug Administration [FDA] owing to allergic responses) and calcium ascorbate are also effective (adapted by the fresh-cut industry in the commercial form of Nature Seal).

The impact of calcium ascorbate on chopped apple was established (Wang et al., 2007). In pear, 4-hexylresorcinol and ascorbic acid were studied. Ascorbic acid did not directly interact with PPO, but it did reduce browning by decreasing oxidised substrates. 4-Hexylresorcinol, on the other hand, interacted with the deoxy form of PPO, inactivating the enzyme in the absence of substrates, or competed for the catalytic site with substrates. POD activity, on the other hand, was connected with browning of sliced melon more than PPO activity.Oxyresveratrol and a mulberry twig extract (mulberroside) combined with isoascorbic acid, calcium chloride, and acetycysteine delayed browning of sliced apples. To keep colour and antioxidant activity, ascorbic acid, citric acid, and calcium chloride were applied to chopped mango.

Antibrowning agents such as ascorbic acid, 4-hexylresorcinol, N-acetylcyteine, and glutathione were tested on cut apple. PPO activity was decreased by N-acetylcysteine and glutathione.POD activity was decreased by ascorbic acid in conjunction with 4-hexylresorcinol, N-acetylcysteine, or glutathione. In general, 4-hexylresorcinol and ascorbic acid were not as efficient as the sulphur compounds N-acetylcysteine and glutathione at the amounts evaluated for browning of chopped apple.Additional natural PPO and browning inhibitors include kojic acid, arbutin, and glabridin, as well as an Artocarpus heterophyllus wood extract that proved effective on sliced apple. Lychee fruit has a brilliant red pericarp that browns after harvest owing to dryness, anthocyanin degradation, and PPO activity. As a result, a lychee fresh-cut product was produced in which the edible aril was separated from the peel and treated with cysteine, ascorbic acid, and 4-hexylresorcinol, as well as osmotic vacuum dehydration, preserving colour and sensory properties.

Coatings

Water loss and dehydration are two issues associated with little preparation of fruits and vegetables. Eating coatings can prevent water loss by serving as a barrier to water vapour transfer or as a sacrificial agent, losing water from the coating before losing water from the product tissue, delaying water loss by the cut product. Coatings can also be utilised to transport the antioxidants, sanitizers, acidulents, chelators, firming agents, and probiotics mentioned above. The issue is that fresh-cut items frequently have considerable water vapour activity on the cut surface, making the application of hydrophobic coatings challenging, despite the fact that they are the best at reducing water loss. Gellan-based films on chopped papaya and apple with antioxidants and live probiotic bilfidobacteria demonstrated excellent water vapour characteristics. Although hydrophilic protein and polysaccharide films are more compatible with a cut surface, when tested on fresh-cut avocados, bananas, and apples, an antioxidant candelilla wax containing Aloe vera decreased weight loss, pH fluctuations, and stiffness (Saucedo-Pompa et al., 2007). When N-acetylcysteine was applied to algenate and gellan-based edible coatings on fresh-cut 'Fuji' apples, it delayed ethylene generation, decreased microbial development, and preserved firmness and colour.

The weight loss of chopped 'Gala' apple was reduced by alginate coating with acetylated monoglyceride. When applied to fresh-cut apples, apple puree-alginate coatings with antimicrobial essential oils (lemongrass, oregano, and vanillin) and antioxidants reduced respiration, ethylene production, and microbial growth but exhibited some ethanol and acetaldehyde formation in the first week of storage. Color changes in candelilla wax are decreased by ellagic acid. These films, in general, decreased the softening of chopped avocado, banana, and apple. Coating chopped apple, carrot, and potato with sour whey powder, soy protein isolate, and calcium caseinate resulted in less colour change and weight loss. Chitosan coatings applied to fresh-cut mushrooms delayed browning and lowered enzyme activity of PPO, POD, catalase, PAL, and laccase, resulting in lower phenolic content.

On chopped papaya, a chitosan covering likewise kept the colour and decreased microbial development. The coatings also suppressed microbial populations and lowered the activities of cellulose, total amylase, and -amylase. Edible coatings such as cellulose, sodium caseinate/stearic acid, whey protein, or xanthan gum have also been used to reduce dehydration of the surface of peeled carrots, which takes on an undesirable white coloration (white blush). Vacuum impregnation of chitosan-based films decreased peeled carrot whitening and water vapour transmission resistance.

Factors Affecting Sensory Quality of Fresh-Cut Produce

Fresh-cut produce is the fastest growing food category in supermarkets in the United States. Fresh-cut salad sales statistics clearly show that customers will pay for fresh-cut produce if the quality and convenience are judged to be greater than or equivalent to uncut items. Convenience is the most crucial motivator for purchasing fresh-cut products .Because commercial testing of product quality is difficult, it is sometimes considered that "if it looks good, it tastes fine." Unfortunately, Contents. Fresh-Cut Fruits and Vegetables Advances the processing quality of intact vegetables and fruits is sometimes assessed nearly entirely by appearance, to the expense of flavour and texture. Customers frequently purchase for the first time primarily on looks, but recurrent purchases are motivated by expected quality elements such as flavour and texture.

It is generally understood that modest processing and wounding have enormous physiological impacts on plant tissue, and the majority of the repercussions of cutting are physiologically harmful, particularly in delicate fruits.Fresh-cut salads and vegetables are doing well in the market since certain significant negative impacts of processing have been mitigated or addressed adequately. Yet, due to a variety of physiological and biochemical reasons, the fresh-cut fruit business has not grown as rapidly as its partner fresh-cut salad and vegetable sector. However, especially in the fresh-cut fruit industry, expansion may be hampered by poor repeat purchases and general consumer unhappiness. This is mostly owing to the intrinsic fragility of ripe fruit with removed skin, but it has also been linked to taste imbalance or loss.

The purpose of this review is to communicate contemporary findings and conclusions linked to factors influencing consumer sensorial acceptance, as well as traditional and recent developments in fresh-cut fruit and vegetable processing that allow for the maintenance or extension of sensory shelf life. Most of the underlying data for this analysis of sensory quality in fresh-cut produce has already been published in other publications. Following that, only recent literature and key things about the sensory properties of fresh-cut food will be covered. The emphasis will be on fresh-cut fruits, with only extremely important vegetable and salad information included. Although volatile and sensory assessment was a primary goal of the study, little to no microbiological treatment effects will be documented

Components of Fresh-Cut Fruit and Vegetable Quality

Color (appearance), fragrance and taste (flavour), texture, and nutritional content are some of the features that explain the characteristics that convey the most significant quality elements in fruits and vegetables. In general, consumers assess a product based on four criteria in the order shown above.Visual signals come first, followed by fragrance, taste, and texture. Aroma refers to a fruit or vegetable's orthonasal (sniff) fragrance, whereas flavour encompasses both scent and retronasal (mouth) taste. Texture is a comprehensive term that includes anything from squeezing to handling stiffness to sensory qualities when chewing. As chewing progresses, the sense of textural quality shifts when items soften due to ripening and storage. Nutritional value is a critical quality characteristic that cannot be seen, tasted, or felt.Although nutritional value is a hidden trait, consumers, scientists, and the medical profession are increasingly appreciating it as phytonutrients, functional foods, and antioxidants become more popular. This chapter will discuss a few noteworthy research involving sensory analysis and factors affecting sensory quality of fresh-cut produce. Nonetheless, the reader is directed to Chapter 6 for a more in-depth summary.

Characteristics of Sensation

Fresh-cut vegetables and salads have high consumer appeal owing to their ease of preparation, versatility, and maybe because their desirable flavour is typically achieved by condiments (croutons, spices, or dressing) and cooking, or because a variety of goods is used. Yet, several vegetables contain distinct scents (e.g., S-compounds) that must be noticed by consumers within their threshold concentration. Consumer approval of fresh-cut fruits, on the other hand, is frequently based on the product's intrinsic flavour and tactile qualities, rather than on accompaniments. Numerous examples show that fresh-cut items lose flavour quality before visual quality.Fruit medleys, as well as dips, spreads, and caramel or chocolate dips for various fresh-cut items, have recently acquired appeal. Similar commercial strategies have been adopted to offset poor market development for fresh-cut fruits, most likely due to customers' anxiety about purchasing items with inconsistent flavour on a regular basis.

Fragrance and Flavor

Customers frequently make their initial purchase based on looks or impulse. Yet, inherent quality qualities like flavour and texture encourage repeat sales. Taste and scent are mostly related to sugars (fructose, glucose, and sucrose), salts, acids (citric, malic, and tartaric), bitter substances (alkaloids and flavanoids), and volatile components. Olfactory nerve endings in the nose detect aroma molecules (e.g., parts per billion). Taste, on the other hand, is the detection of nonvolatile chemicals by several types of receptors in the tongue.

Processing of Fresh-Cut Fruits and Vegetables Advances (e.g., parts per hundred). Taste is a complicated "trait" that is difficult to understand. Dozens to hundreds of volatile and semivolatile chemicals may be responsible for a fruit or vegetable's distinctive scent. Several of these critical substances will be present in such minute amounts (parts per billion) that they will need the use of costly and complicated analytical equipment.

Then, determining which volatile components actually impact the flavour of a fruit or vegetable necessitates method-dependent gas chromatography (GC) or gas chromatography/mass spectrometry (GC-MS) separation, gas chromatography/olfactometer (GC-O), or sensory analysis, all of which are complicated, labor-intensive, and costly. Instrumental procedures must be used to quantify chemical concentrations in a commodity, and sensory measurements of odour threshold or taste units must be performed to assess the contribution of that specific compound. As a result, taste detection, significance, and concerns are frequently disregarded in the business owing to pragmatism.

Flavor volatiles in fruits and vegetables are produced through a variety of biosynthetic pathways (carbohydrates, amino acids, fatty acids, oxidations, and ß-oxidation) and include a diverse range of molecular weight alcohols, aldehydes, esters, furanes, glucosinolates, ketones, lactones, nitrogen- and sulfur-containing compounds, terpenes, and other compounds. Volatile esters frequently contribute significantly to the fragrances of fruits such as apple, banana, pear, strawberry, and melon. Taste loss during fresh-cut storage can be caused by senescence and may be mediated by catabolic, metabolic, and diffusional processes (Beaulieu, 2006a, 2007; Forney, 2008). Taste variations that occur during fresh-cut storage may also have an impact on the consumers' experience and decision to purchase again. Although fresh-cut was not specifically investigated, recent in-depth analyses of fruit and vegetable flavour and sensory assessment were published.

Numerous concepts and topics discussed in that paper, as well as in Barrett et al. (2010), are pertinent and applicable in fresh-cuts.Some recent investigations have shown that a product's sensory qualities may deterioratebefore its physiological look deteriorates. Kader (2003) proposed a hypothetical postharvest quality figure that was adapted for inclusion herein to generalise how flavour quality compares with visual and textural quality in fresh-cut fruits. An informal tasting panel decided, for example, that fresh-cut honeydew melon held in air at 5°C for 6 days lacked appropriate textural features and had flat flavour. After 5 days at 4°C, fresh-cut orange segments with acceptable look after 14 days were found to have inadequate flavour quality (Rocha et al., 1995). Similarly, disagreeable flavour was the limiting factor in sliced wrapped watermelon held at 5°C for 7 days, despite the fact that scent was still acceptable and microbiological populations were not troublesome until day 8. After that, modified atmosphere packaging (MAP) has been researched as a method of extending the taste and fragrance attributes of fresh-cut fruit.

Customers often rank taste as the most essential quality trait for fruits and vegetables; nevertheless, textural flaws and the interplay of flavour and texture are more likely to result in fresh product rejection. The quality trait that assists both the industry and the customer in determining the acceptability of cut fruits and vegetables. The term texture refers to a food's structural and mechanical properties, as well as the sensory components in the hand and mouth, all of which can be measured using a variety of destructive and nondestructive instrumental or objective methods Texture examination is most typically accomplished by the application of a destructive force, such as piercing or compression. A piercing test on the texture analyzer revealed consistent firmness loss in stored fresh-cut cantaloupe. These tests, due to their empirical character, do not give a knowledge of food microstructure or force-deformation and failure processes at the cellular level. The three-dimensional network of plant cell walls remains relatively unsolved, yet it dominates the sense of consistency, smoothness, and juiciness in fruit and vegetable tissues. According to consumer and panel research, consumers or panels are frequently more sensitive to modest variations in texture than flavour

Nutritional Value

After preparing fresh cuts (wounding), the antioxidant capacity of fruit or vegetable tissue may increase (carrot, celery, lettuce, parsnip, purple-flesh potato, sweet potato, and white cabbage) or decrease (melon, potato, red cabbage, and zucchini) during storage (Kang and Saltveit, 2002; Reyes et al., 2007; Reyes and Cisneros-Zevallos, 2003). (Oms-Oliu et al., 2008b; Reyes et al., 2007). Excessively low O2 (2.5 kPa) and high CO2 (7 kPa) concentrations accelerated the production of phenolic compounds, decreased vitamin C, and boosted peroxidase activity in fresh-cut 'Piel de Sapo' melon during experiments with varying starting in-package O2 and CO2 values (Oms-Oliu et al., 2008b). This might be because internal package O2 concentrations had dropped below 1% after 9 days of storage.

1. Depending on the firmness and texture
2. Appearance & Visual Quality (Normal - Retail + consumer error)
3. Taste and/or nutritional quality (rare!)

Breakthroughs in Fresh-Cut Fruit and Vegetable Processing

Finally, 70 kPa O2 storage was proposed as a potential ideal atmosphere since it minimised anaerobic fermentation, wound-induced stress, and deteriorative alterations caused by increased peroxidase activity in cut tissue.Fresh-cut pears soaked in N-acetylcysteine plus glutathione (0.75% w/v, each) to avoid browning were packaged in active flush MAP delivering low O2 atmospheres (2.5 kPa O2) and high O2 atmospheres (70 kPa O2).When compared to 70 kPa of O2, the synergistic antioxidant treatment with low O2 maintained the highest levels of vitamin C, chromogenic acid, and antioxidant capacity (Oms-Oliu et al., 2008a). The results reveal that using glutathione and N-acetylcysteine increased the synthesis of phenylpropanoids in fresh-cut pears held in a low O2 environment (Oms-Oliu et al., 2008a). Fresh-cut apples treated for 3 minutes with 1% ascorbic acid and 1% citric acid had similar improvements in antioxidant activity.

In certain fresh-cut fruits, vitamin C and carotene deteriorated relatively little after short-term storage (approximately one week) (Wright and Kader, 1997a, 1997b). Nevertheless, ascorbic acid and vitamin C concentration dropped after cutting, particularly in fresh-cut storage for extended periods of time. After 6 days in clamshell containers at 5°C, vitamin C loss was 5% in mango, strawberry, and watermelon pieces, 10% in pineapple pieces, 12% in kiwi slices, and 25% in cantaloupe cubes. Vitamin C concentration in stored (4°C) fresh-cut cantaloupe decreased considerably after about 1 week, and the drop was independent of initial processing maturity (Beaulieu and Lea, 2007). After 6 days at 5°C, carotenoids reduced by up to 25% in pineapple pieces and 10% to 15% in cantaloupe, mango, and strawberry pieces.Over 21 days of fresh-cut storage at 5°C, ascorbic acid dips decreased browning and degradation in fresh-cut 'Ataulfo' mango and preserved vitamin C and ß-carotene levels. Total ascorbic acid is preserved substantially better in processed iceberg lettuce when there is less cell damage after cutting.

CHAPTER 7

ASPECTS AND SUBSTANCES INFLUENCING FRESH-CUT SENSORY QUALITY

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In actuality, studies and reviews have clearly demonstrated that a number of critical preharvest elements (genetics, cultural practises, environment, and harvest maturity) can predict or decide ultimate fruit and vegetable flavour quality.In practise, however, the integration of all aspects from field to fork, including variety selection, horticultural practises, harvest operations, shipping, cooling, washing, processing operations, packaging, cold chain integrity, distribution, marketing, and shelf life of the fresh-cut product, ultimately determines sensory quality and consumer appraisal. As a result, because vertically integrating the entire chain and managing it flawlessly is a big problem, many processors merely attempt to guarantee the finest possible quality produce arrives at their plant.

Sensory Quality of Fresh-Cut Produce

Next they process (after passing through a series of insignificant to tough internal quality control tests), package, and distribute what they have. As a result, intrinsic fresh-cut attributes may not always meet one's expectations for optimal flavour, fragrance, and sensory quality. Using the "best" cutting and processing methods, as well as packing and distribution, becomes essentially a game of retaining the initial quality for the longest rationally viable time period to ensure sales, safety, and a delighted consumer. To that purpose, there are various aspects that influence the sensory quality of fresh-cuts. Variety, maturity, season, precutting treatments (ethanol, 1-MCP, hot water, insect sanitation, heat shock), processing technique and treatments or aids (antibrowning, firmness retention, 1-MCP, edible coatings, microbiological sanitation), combined and synergistic quality retention treatments or hurdles, packaging (containers, form and fill, deli cups, active flush and passive MAP, film-sealed trays, and so on), and temperature management are among them. This evaluation will focus on key colour, appearance, texture, flavour and fragrance aspects, and nutritional content in newly published literature for fresh-cuts using the aforementioned methods.

Precutting Treatments or Whole Fruit

The effectiveness of 1-MCP treatment varies depending on various aspects, including the concentration of 1-MCP employed, storage condition and duration, climacteric vs nonclimacteric fruit, and fruit maturity at the time of application. Commercial usage of climacteric fruits necessitates a delicate balancing act between cultivar-dependent 1-MCP concentration and exposure intervals that delay but do not prevent ripening (Blankenship and Dole, 2003;

Calderon-Lopez et al., 2005; Watkins, 2008). Other precutting procedures that have been investigated include ethanol vapour and heat or hot water treatments to intact commodities.

1-MCP applied to partially ripe fruit prior to cutting reduces firmness and colour loss in fresh-cut kiwi, mango, and persimmon. 1-MCP reduced ethylene production, respiration, softening, colour change, and aroma/volatile chemical synthesis in fresh-cut apples. Thorough volatile and genetic investigation reveals that marketing 1-MCP-treated fruit soon after treatment may result in fruit with a low possibility of ester volatile recovery, even when browning is reduced with NatureSealTM. Nevertheless, volatile recovery has been reported in long-term apple preservation, but this is variety dependant (Watkins, 2008). Similarly, 1-MCP treatment of whole pears reduced aromatic volatile generation by the fruit but did not impair volatile synthesis or sensory (texture) acceptance following long-term storage. This study, however, did not include fresh-cuts. As a result, the maturity and variety-dependent efficacy of 1-MCP is problematic and must be severely reviewed in terms of producing organoleptically acceptable fresh-cuts.

The postcutting quality and shelf life of fresh-cut fruit items are affected by both harvest maturity and ripeness stage. Because many fruits are selected before they are fully mature, the topic of when climacteric fruit should be utilised for fresh-cut processing to maximise product shelf life and eating quality arises. Fresh-cuts may be prepared with firm fruit that was picked somewhat immature in order to survive mechanical damage during postharvest processing and give good aesthetic quality and acceptability by merchants and customers. Consumer preferences within a particular fruit type are frequently cultivar dependant and frequently dictated by maturity stage (Harker et al., 2003). Firmer fruit is less ripe and consequently tastes more acidic or "sour," with a volatile profile high in aldehydes that delivers green grassy scent and flavour characteristics. Softer fruit, on the other hand, is often considerably riper, has lower acidity, and a volatile profile dominated by esters, which offer characteristic fruity scent and flavour qualities.

Despite reports of dull flavour towards the end of storage, sliced mature-green tomato fruit ripened properly and gained equivalent eating quality to fruit sliced after the whole fruit ripened. Yet, the majority of fruits do not follow this pattern. In general, a harmful tradeoff appears to exist between firmness and acceptable volatiles and flavor/aroma qualities in fresh-cut fruits made with less mature fruit. Mango fruit processed at the firm-ripe stage, for example, had lower aroma/smell scores and less ripe scents than soft-ripe fruit, while firm-ripe wedges were stored under passive MAP for 11 days against 7 days for soft-ripe wedges.Certain ripening-related phenomena, such as softening, will occur in sliced pear and peach fruit, but other ripening-related processes, such as taste development and texture, appear abnormal if the fruits are treated at an extremely immature stage.

Mature green apple slices retained their original firmness and colour better than partially ripe and ripe slices, and slices of slightly underripe 'Conference' pears demonstrated less browning and softening than those from more ripe fruit (Soliva-Fortuny et al., 2002b) (Soliva-Fortuny et al., 2004). In addition, pear slices processed at half ripe maturity were more suited for obtaining fresh-cut goods than mature green and ripe fruit. As a result, in climacteric fruits, early fruit hardness is a strong predictor of needed fruit maturity for optimal postcutting quality.The level of taste volatiles recovered in fresh-cuts from soft-ripe vs firm-ripe mangos (Beaulieu and Lea, 2003), and 1/4-, 1/2-, 3/4-, and full-slip 'Sol Real' cantaloupes (Beaulieu and Lea, 2003). (Beaulieu, 2006b). The level of taste volatiles extracted from 'Athena' and 'Sol Real' cantaloupes is considerably affected by harvest ripeness. Increased maturity was related with higher total compounds, total esters, nonacetate esters, aromatic (benzyl) and sulphur compounds, and decreased levels of acetates and aldehydes, and maturity-associated volatile trends were retained after fresh-cut storage.

Sensory Quality of Fresh-Cut Produce Factors

Cantaloupe fruit picked at various stages of maturity yields stored cubes with considerable differences in postharvest quality, taste, sensory, and textural qualities.In general, less developed fruit cubes that were very firm lacked taste volatiles (Beaulieu, 2006b) and had worse sensory scores. High-quality fresh-cut cantaloupe can be cooked using fruit obtained at least 1/2-slip ripeness, with 3/4-slip ripeness preferred, but not 1/4-slip ripeness.

The nonacetate esters to acetate esters ratio altered evenly throughout fresh-cut cantaloupe storage, regardless of initial processing maturity (Beaulieu, 2006b). In preserved fresh-cut apple and honeydew, the ester: acetate ratio altered in a similar way (Beaulieu, 2006a). Further data analysis in fresh-cut cantaloupe revealed many associations between taste compounds and classes of compounds between several qualitative, textural, and sensory aspects (Beaulieu and Lancaster, 2007). The descriptive sensory analysis, on the other hand, was unrelated to the threshold volatile concentrations. Instead, we performed analyses of variance (year maturity day), created correlation coefficients (e.g., Table 5.1), and showed the association using h-plots. The Pearson's product-moment correlation coefficient is displayed on an h-plot, where clusters of positively correlated variables correspond to clusters of radii and groups of clusters separated by 180° are negatively linked. Sweet taste and a*, b*, a*/b*, and%Brix were shown to have some of the highest sensory and physiological relationships. Cucurbit, denseness, and water-like were inversely associated to a*, b*, a*/b*, and%Brix, but positively related to L* and desiccation. The strongest connections in the research were from Young's modulus (firmness). It was positively connected with nonacetate esters and adversely correlated with relative proportion aromatic acetates, total benzyl compounds, and acetates.

Processing Methods

Most fresh-cut processing treatments and dips are dissolved in water or sprayed onto surfaces for antibrowning (e.g., apple, lettuce, pear, zucchini), antibacterial (to assure food safety), and firming agents. This issue will not be discussed because a study of prospective substitutes for chlorine usage during processing, as well as alternate washing regimens (mostly antimicrobial), was recently published (Rico et al., 2007). Many chemicals and classes of compounds have been tried alone and in combination with or without additional barriers (e.g., calcium, CA, MAP, heat, ultraviolet [UV], sanitation) throughout over 20 years of new study. Early therapies for quality retention were classified as either physical or chemical and were summarised for fresh-cut fruits. There are other commercial items available that will not be mentioned. Lately, therapies have grown more diverse, and synergistic approaches to quality enhancement using integrated physical and chemical processes have begun. The emphasis in this section is on recent or unique fresh-cut studies regarding taste and fragrance.

Firmness Retention and Antibrowning

A significant amount of effort has been done in the fresh-cut sector to maintain or improve storability using technology and chemical applications (mostly antibrowning, antibacterial, and firmness agents). Numerous researchers are now working on synergistic therapies using MAP, 1-MCP, coatings, and dips.

Following that, numerous issues will be discussed in those parts. Some browning treatments are complimentary in that they contain calcium or salts, which may aid firmness retention. Regrettably, several treatments that are meant to prevent enzymatic browning or enhance texture might introduce off-flavors. Calcium chloride concentrations more than 0.5% caused perceptible off-taste in melon slices, but calcium lactate increased firmness without imparting a bitter flavour. Off-odors were discovered in potato strips after treatment with sodium sulfite and storage in passive MAP for 14 days at 4°C, and off-flavor was seen in 'Bartlett' and 'Bartlett' varieties.

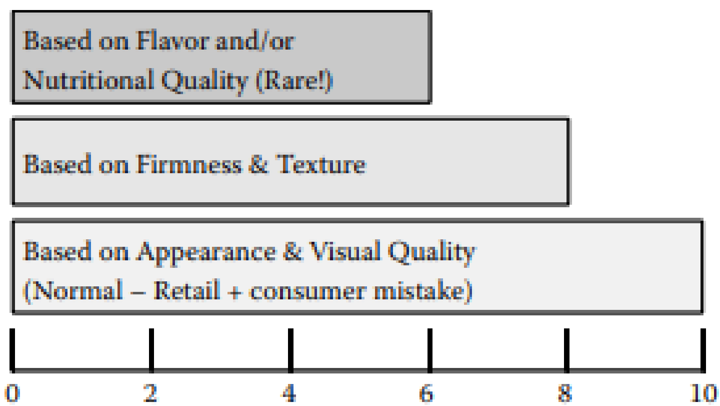

Figure 7 .1: represents the Fresh-cut life (days) under optimum conditions

Inhibition of Ripening

When 1-MCP was mixed with CaCl2 (1%) + CA (3 kPa O2 + 10 kPa CO2) in strawberry wedges, a synergistic effect was noticed, as it reduced softening, loss of appearance quality, changes in TA, and microbiological development, resulting in a shelf life of 9 days (vs 6 days for the control) at 5°C (Aguayo et al., 2006). Fresh-cut grapes with stems attached (1 to 2 mm) that received a hot water dip (55°C for 5 minutes) had superior quality, sensory scores nearly equal to controls, and very little decay as evidenced by the lowest population of yeast and mould, lactic acid bacteria, and total mesophilic aerobic bacteria (Kou et al., 2007). Even though these results are highly promising, manually cutting individual berries from grape bunches prior to treatment and packing may not be economically practicable. Informal sensory characteristics (firmness and Volatile Outer Circle = Physiological)% 3-methylthiopropylacetate% ethyl butanoate% non-acetate esters% ethyl 2-methylpropanoate% ethyl hexanoate% ethyl hexanoate pH a*, b*, and a*/b*

% alcohol % eucalyptol Cube Brix Average firmness Slope; Bioforce; TA; YM; Bioarea

Color

Aromatic acetates (%)

L*; % 2-methylbutyl acetate% benzyl acetate Sulfur desiccation percentage

(Z)-6-nonenal (E,Z)-2,6-nonadienal (E,Z)-2,6-nonadienal (E,Z)-2,6-nonadienal (E,Z)-2,6-n

Edges of Slurry Brix % aldehydes; % (E)-2-nonenal % total esters

Graph 5.3 Physiology versus volatile correlations in fresh-cut cantaloupe ('Sol Real') maintained at 4°C for 14 days (Y M D, year by maturity by day). According to Beaulieu and Lancaster (Beaulieu J.C., and V.A. Lancaster. 2007. Correlating volatile chemicals, quality metrics, and sensory qualities in stored fresh-cut cantaloupe), 55 compounds were positively detected and measured. Agriculture and Food Chemistry 55(23):9503-9513). The abbreviations for instrumental firmness measurements and subjective quality acronyms. Color measurements a* and b*, as well as subjective evaluations for edges, scent, and rotting, showed no relationship with any volatiles.Factors Influencing Sensory Quality of Fresh-Cut Fruit 127 appearance) were maintained for 6 days in 1-MCP-treated cut papaya compared to 2 to 3 days in controls housed at 5°C, and stiffness dropped 50% in 1-MCP-treated slices compared to 75% in controls (Ergun et al., 2006).

Based on firmness and sensory assessments, 1-MCP treatment (1 L L1 for 24 h at 20°C) improved the storage life of fresh-cut 'Galia' melon maintained at 5°C by 2 to 3 days. In 1-MCP-treated fresh-cut tissue, water soaking and mesocarp softening were greatly inhibited or delayed (Ergun et al., 2007). Nevertheless, the effect of 1-MCP treatment on the firmness retention and water soaking of other fresh-cut melon cultivars was inconsistent in other tests. As a result, applying 1-MCP to muskmelons prior to fresh-cut processing was not advised. According to Huber (2008), because wounding overrides ethylene signalling components, the benefits conferred by treating whole fruits with 1-MCP in stored fresh-cut tissues may be significantly dampened.

Watermelon is a nonclimacteric crop that is extremely susceptible to ethylene. Low dose 1-MCP (18 h of 0.5 or 1.0 L L-1) treatments were applied to entire watermelons prior to ethylene exposure (5 days of 10 L L-1) in an attempt to alleviate mixed commodity-related and fresh-cut deterioration. In fresh-cut watermelon slices held 12 days under passive MAP at 5°C, 1-MCP prevented ethylene-mediated quality decline.A sensory panel revealed that exposing mangoes to ethanol fumes for more than 20 hours resulted in stored (7°C) fresh-cuts with greater firmness and acidity. Nonetheless, off-flavors formed, and, as in earlier studies, harvest ripeness and heat treatment had an impact on the findings (Beaulieu and Saltveit, 1997). Yet, shorter ethanol exposure times (8 to 10 h) have been proposed as a feasible safe microbial control in fresh-cut production (Plotto et al., 2006). The use of ethanol vapour treatment on intact apples to decrease ethylene production and minimise deterioration in fresh-cut slices enhanced shelf life but resulted in changed or off-flavor apples (Bai et al., 2004). Pretreating intact broccoli with ethanol vapour prevented senescence in 8-day-old fresh-cut broccoli florets kept at 10°C (6 mL kg–1 for 5 h). Tissue ethanol and acetaldehyde concentrations increased dramatically, although ethanol dropped sufficiently after 1 day to avoid unpleasant or alcoholic odours.

There were no consistent changes in soluble solids, ascorbic acid, fluid loss, scent and aesthetic ratings in fresh-cut cantaloupe cubes made from hot water-treated cantaloupes (76°C for 3 min). Because the hot water treatment dramatically lowered total plate count (TPC), yeast and mould counts on the rinds and resulted in lower TPC on the cubes, it might become a one-step or hurdle technique to improve microbiological safety without compromising cut melon quality.Moderate heat pretreatments of intact early maturity (firm ripe) kiwifruit at temperatures below 45°C for less than 25 minutes increased firmness quality; however, no improvement was detected in soft ripe fruit, which would likely have superior flavour and consumer qualities.Technological Developments in the Processing of Fresh-Cut Fruits and Vegetables.

Dips and coatings that are edible

As transporters of functional compounds such as antibacterial and antioxidant agents, edible coatings may potentially improve the microbiological safety of fresh-cut fruit. Creating and optimising diverse formulations presents a number of obstacles (Lin and Zhao, 2007; Min and Krochta, 2005; Olivas and Barbosa-Cánovas, 2005). Inadequate moisture barrier, inadequate coating coverage, poor coating adherence, and fresh-cut surfaces soaked with juice can actually breakdown coatings that are absorbed rather than drying to produce a homogeneous boundary layer are all examples. There are also concerns about possible off-flavors caused by anaerobic respiration, which causes the creation of ethanol and acetaldehyde with different coating materials, or the trapping of volatiles in sealed tissue. Apple slices coated with soybean oil emulsion or carboxy methylcellulose lost aroma volatiles critical to the taste character (Bai and Baldwin, 2002). On the other hand, covering fresh-cut mango cubes with 1% polysaccharide carboxy methylcellulose 0.5% maltodextrin resulted in improved volatile retention than uncoated fruit, while taste panellists detected no difference between treatments (Plotto et al., 2004). The absence of ethanol and acetaldehyde buildup after 6 to 9 days in three cultivars ('Keitt,' 'Kent,' and 'Ataulfo') of stored (5°C) fresh-cut mango was thought to be a good predictor of the beneficial impact of commercial edible coatings.

Malic and lactic acids were integrated into soy protein plus glycerol films that were used to coat fresh-cut cantaloupes that were preserved at 5°C without compromising their sensory qualities. At 7 days at 5°C, the sweetness of cubes coated with soy protein plus glycerol and lactic acid was greater than that of noncoated and soy protein plus malic acid coated samples. Several sensory qualities of flavour and look in the cube coatings, on the other hand, revealed no significant variation on days 7 and 14. As a result, there appeared to be no significant favourable (e.g., taste preservation) impacts. Fresh-cut 'Fuji' apples treated for 1 minute with ascorbic acid and N-acetylcysteine (10 gL-1, each) showed a fivefold rise in peroxide levels, indicating oxidative injury to the tissue. Further research is needed to evaluate whether the total antioxidant capacity is harmed. All edible coating treatments tested on coated apples slices maintained in passive MAP pouches at 3°C for up to 14 days resulted in higher sensory ratings (colour, firmness, and taste) for all quality variables evaluated. Composite coatings of whey proteins (hydrophilic phase) and beeswax or carnauba wax (lipid phase) provided antibrowning effects on fresh-cut apples, and the incorporation of antioxidants (ascorbic acid, L-cysteine, and 4-hexylresorcinol) into the coating reduced browning when compared to the antioxidant alone sensory (Perez-Gago et al., 2005, 2006). Sensory panels, on the other hand, were capable of distinguishing samples treated with whey protein-based coatings and when cysteine was added.

Alginate-based edible coatings were recently studied in a variety of fresh-cut fruits. Apple wedges coated with three alginate formulations (alginate, alginate-acetylated monoglyceride-linoleic acid, and alginate-butter-linoleic acid) and kept at 5°C showed little weight loss, retained firmness, browning inhibition, and no anaerobic respiration (Olivas et al., 2007). Substantial alterations in several essential flavor-related apple volatiles were detected, which the authors suggested may be linked to the coating's linoleic and sorbic acid contents getting metabolised; nevertheless, no accessory sensory assessments were noted.

Edible coatings based on alginate, pectin, and gellan were applied to fresh-cut 'Piel de Sapo' melon held under passive MAP for 15 days at 4°C, with sensory evaluation on day 7. The pectin coating had the highest quality retention (7 days), whereas the gellan coating had the worst odour, colour, and taste. In general, edible coatings avoided desiccation and preserved firmness, whereas pectin-based coatings best preserved sensory properties in fresh-cut melon (Oms-Oliu et al., 2008e). It was also recently reported that fresh-cut papaya cylinders maintained at 4°C for 8 days in polyvinyl chloride (PVC) cups with airtight PVC lids were coated with alginate- (2% w/v) or gellan-based (0.5% w/v) coating formulations. Coatings containing 2% glycerol plus 1% ascorbic acid or 1% glycerol plus 1% ascorbic acid somewhat enhanced water barrier characteristics and stiffness, and the inclusion of ascorbic acid aided in the preservation of nutritional quality during storage (Tapia et al., 2008). Unfortunately, no sensory or scent properties were reported.

Edible films have the ability to combine synergistic therapies as well. Essential oils of cinnamon, palmarosa, and lemongrass were recently combined into edible alginate coatings and tested as natural antibacterial agents on 'Piel de Sapo' fresh-cut melon. This research produced positive microbiological results, but there were some worrisome stiffness and sensory concerns. The integration of lemongrass into the edible coating considerably influenced firmness, and cinnamon oil resulted in inferior odour and taste qualities and was not acceptable. Panelists approved of palmarosa oil (0.3% mixed into the edible coating), which prevented native flora development, decreased the Salmonella enteritidis population, and was proposed as a viable conservation technique in fresh-cut melon. Plant-derived essential oils (oregano, cinnamon, and lemongrass) integrated with apple-based antimicrobial edible films show antibacterial properties that are promising. Unfortunately, no research has been conducted to test effectiveness on cut fruits and if the films may entrap volatiles.

Peeled baby carrots dipped in xanthan gum solution containing 5% calcium lactate plus gluconate and 0.2% -tocopherol acetate and kept at 2°C for up to 3 weeks showed better surface colour with no negative impacts on taste, texture, fresh scent, and flavour (apart from a somewhat "slippery" surface). Vitamin E (0.4% to 0.8% -tocopherol) incorporation into honeybased vacuum impregnation (VI) solutions was recently employed to retain fresh-cut pear quality. After 7 days in clamshell containers at 2°C, instrumental colour analysis and sensory assessment revealed that VI-fortified pear slices had considerably higher lightness, reduced browning index, and higher consumer approval rating than unfortified control. Similar findings were obtained for fresh-cut VI-treated apples kept at 3°C for up to 14 days. Nevertheless, vacuum infiltration technologies may be met with resistance in the "new-cut" field.

Several similarities have been reported in the literature where increasing anaerobic volatile accumulation or marked ester imbalances in fresh-cut MAP apples, durian, and cantaloupe were not associated with the development of off-odors or were negatively appraised by sensory or human evaluations. Overall terpene levels in fresh-cut Keitt and Palmer mangoes stored in passive MAP declined by 47% and 79% after 7 and 11 days, respectively, and this was related with loss of acceptable scent. Using physiological measurements, this rendered fresh-cuts unmarketable after 7 days for soft-ripe cubes and 11 days for firm-ripe cubes (Beaulieu and Lea, 2003). Remarkably, buildup of anaerobic volatiles (acetaldehyde, ethanol, ethyl acetate, and ethyl butanoate) in the package headspace environment had no detrimental effect on aroma/smell rating.

After 7 days of storage, fresh-cut durian (arils) wrapped in low-density polyethylene (LDPE) film and stored at 4°C lost 53% of total volatiles, including 77% of esters, but fruity and sweet notes could still be perceived by panellists using quantitative descriptive analysis, even when ester concentrations were not detectable. Just 14 days later, the loss of most esters associated well with the decline in panellists' perceptions of fruity fragrance intensities.Fresh-cut apples dipped in 10 g L-1 ascorbic acid and 5 g L-1 calcium chloride and packaged under different MAP resulted in increased respiration coefficients, which reduced consumer acceptance beyond the second week of storage, despite the fact that reduced ethylene and CO2 production limited fermentative metabolite accumulation (Soliva-Fortuny et al., 2005). Despite considerable ester changes, sensory panels judged that kept 'Gala' apple slices (14 days at 1°C) in barrier bags preserved acceptable taste and acquired no off-flavors or fermented flavours (Bett et al., 2001). When 'Gala' apple slices were held in perforated polyethylene bags at 5.5°C for 7 days, the concentration of ethyl ester increased 11-fold, while the concentration of acetate ester decreased by around 50%, but no significant changes in apple-like flavour were linked with these changes (Bai et al., 2004). Similarly, nonacetate esters increased 87% and acetate esters decreased 66% in fresh-cut cantaloupe cubes stored at 4°C for 14 days, but sensory analysis revealed transient increases followed by slight declines in some flavour and aroma attributes, with the exception of mustiness, which increased after 12 days (Beaulieu et al., 2004). As previously stated, the ratio shift of nonacetate esters (raised) to acetate esters (decreased) during fresh-cut storage of cantaloupe was linear and homogeneous, regardless of maturity (Beaulieu, 2006b), and comparable patterns were seen in freshcut apple and honeydew.

Rapid loss of low molecular weight esters (C8) from thin sliced cantaloupe held in open or closed Petri dishes was attributed to off gassing due to the esters' high vapour pressures and low boiling points in one of the few studies that considered diffusion of volatiles at the cut boundary as a mechanism of flavour loss in fresh-cuts. There was no indication of catabolic loss by recovery of esterasemediated volatiles, which matched with the discovery that esterase activity decreased in thin-sliced cut cantaloupe after storage. Additionally, only secondary volatiles were collected, which were mostly related to lipid oxidation and carotenoid breakdown (Beaulieu, 2007). The boundary layer effect was investigated further by sampling equatorial melon tissue as thin slices (2-mm thick) rather than typical cubes washed (1 minute at 5°C) and kept at 5°C. Following the GC-MS volatile determination, cubes were cut to resemble thin-sliced tissue, and the inside 1 cm3 was sampled after the outside tissue was removed. Table 5.2 shows that washed thin-sliced tissue showed somewhat higher ester recovery on day 0, followed by considerable loss (62%) after 3 days storage compared to both tissue types from cubes. As compared to previously reported ester losses in a comparable system without washing, rinsing the samples reduced short-term boundary layer ester loss. Our results clearly show that both interior and exterior cube tissue had almost comparable ester profiles throughout storage, but esters rapidly diffused away from the thin-sliced tissue during storage, with few exceptions, across all molecular weights. Thin-sliced tissue has nearly four times the surface area per unit volume of a normal fresh-cut cube. As a result, not only is cutting tool sharpness and relative humidity during storage vital for quality preservation, but so are the size of the tissue cut and surface area to unit volume in terms of key volatile diffusion and loss.

CHAPTER 8

PACKAGING AND STORING

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Following reducing product temperature, modified atmosphere packaging (MAP) is regarded as the second-best strategy for improving maintaining quality and shelf life for a variety of fresh-cut commodities. MAP increases the shelf life of fresh-cut products by decreasing O2 concentrations and increasing CO_2 concentrations in the package atmosphere, which is accomplished through the interaction of respiratory O_2 uptake and CO_2 evolution of the produce, as well as gas transfer through the package films. In theory, MAP maintains the freshness of fresh-cut items by matching the oxygen transmission rate (OTR) of the packing film to the product's respiration rate. Since films have a fixed OTR per temperature, incorrect or variable temperatures may often speed product degradation and disrupt the usual fragrance and flavour characteristics in MAP. Here is where one of the most serious issues with MAP arises: fine-tuning a model to achieve equilibrium conditions is very difficult unless the package is kept at a tightly regulated temperature.

MAP settings that are optimised in research investigations are frequently degraded in commercial applications. Unfortunately, there are some potential negative effects of MAP, such as water condensation within packages due to temperature fluctuations, abnormal ripening in certain fruits, and the development of physiological disorders, which frequently result in anaerobically produced off-flavors and off-odors, as well as a decrease in some bioactive compounds (Artés, 2006). Furthermore, because films ma6y lack proper permeability, enhanced fermentation reactions and unsatisfactory product quality are frequently seen commercially prior to the conclusion of the "normal" shelf life. The effects of MAP on the quality of fresh-cut fruits and vegetables have been extensively reviewed in recent years, and this chapter will focus on studies that incorporate sensory and flavour aspects.

When compared to passive MAP and perforated films, fresh-cut cantaloupe cubes retained best under active MAP (4 kPa O2 + 10 kPa CO2) at 5°C for 9 days and maintained faint melon scent after 12 days. However, tissue translucency and off-odor development reduced the shelf life (5 to 7 days) of cubes stored in perforated film containers (Bai et al., 2001). An intermediate state of ripeness (slightly underripe) upon processing was shown to be the best for extending the shelf life of fresh-cut 'Piel de Sapo' melon kept at 4°C under active MAP (2.5 kPa O2 + 7 kPa CO2). Furthermore, by avoiding alcohol buildup, colour loss, translucency, and flesh softening, 1% ascorbic acid and 0.5% calcium chloride increased shelf life to 10 days. Sadly, no sensory or customer review was provided by the authors.

Color and texture, as assessed by instruments and trained sensory panels, were constant in fresh-cut cantaloupe undergoing electron (E)-beam irradiation (0, 0.5, and 1 kGy) stored under actively flushed MAP (4 kPa O2 + 10 kPa CO2) for up to 17 (+/-3) days storage at 3°C (Boynton et al., 2006). The 1-kGy sample scored best in sweetness and cantaloupe taste intensity, and lowest in off-tasting.

Controlled atmospheres of low O2 and high CO2 (4 kPa O2 + 15 kPa CO2, and 21 kPa O2 + 15 kPa CO2) lowered respiration rate and ethylene emission, resulting in fresh-cut 'Amarillo' melon with superior sensory quality than controls stored for up to 14 days at 5°C. Melon slices stored in both CA had a shelf life of 14 days, with 4 kPa O2 + 15 kPa CO2 being superior for firmness (Aguayo et al., 2007). For 2 weeks at 4°C, superatmospheric O2 (70 kPa O2) packing of fresh-cut 'Piel de Sapo' melons predipped in 0.5% calcium chloride preserved instrumental firmness and chewiness while avoiding fermentative reactions (Oms-Oliu et al., 2008d). Superatmospheric O2 treatment of 'Flor de Invierno' fresh-cut pears in 0.75% N-acetylcysteine and 0.75% glutathione resulted in a drastic change in several qualitative features, notably excessive ethanol buildup (Oms-Oliu et al., 2007b). For both winter and summer season fruit, fresh-cut honeydew cubes stored 11 days in active MAP (5 kPa O2 + 5 kPa CO2) had higher visual quality and fragrance than passive MAP (Bai et al., 2003). Passive MAP (final atmosphere of 4 kPa O2 + 12 to 13 kPa CO2) using three commercial films preserved fresh-cut Amarillo melon sensory quality and microbiological safety for 14 days at 5°C.

Partly ripe fresh-cut 'Conference' pears treated with browning inhibition (10 g L-1 ascorbic acid and 5 g L-1 calcium chloride for 1 minute) and packaged in MAP (2.5 kPa O2 + 7 kPa CO2) maintained good sensory quality throughout three weeks at 4°C storage.Nevertheless, both low O2 and high CO2 levels were shown to have a negative impact on quality, leading the authors to suggest that greater CO2 and O2 transmission films are necessary (Soliva-Fortuny et al., 2007). In fresh-cut pears, antioxidant treatments (0.75% N-acetylcysteine + 0.75% glutathione) combined with active low O2 MAP avoided browning and preserved vitamin C, chlorogenic acid, and antioxidant capacity (Oms-Oliu et al., 2008a). Interestingly, the authors were comparing high O2 MAP to typical MAP, which resulted in worse quality (colour and physiological; 134 Advances in Fresh-Cut Fruits and Vegetables Processing sensory was not stated). Low O2 MAP (2.5 kPa O2) also best preserved vitamin C and phenolic content in fresh-cut 'Piel de Sapo' melon storage (Oms-Oliu et al., 2008b). Packing fresh-cut apple and pear under high N2 (100 kPa) pressure resulted in gradual product deterioration and virtually linear texture loss throughout storage (Soliva-Fortuny et al., 2002a, 2002b).

Fresh-cut pineapple soaked in 0.25% ascorbic acid and 10% sucrose for 2 minutes and kept at 4°C under active MAP (4 kPa O2 + 10 kPa CO2) retained sensory quality for 7 days, but passive MAP generated off-flavor after 3 days (Liu et al., 2007). Pineapple chunks stored in MAP (1.5 kPa O2 and 11 kPa CO2) for 14 days at 0°C showed no off-flavors and retained acceptable appearance, however keeping at 5°C caused anaerobiosis (1 kPa O2 and 15 kPa CO2), resulting in a minor off-odor upon opening that immediately disappeared (Marrero and Kader, 2006).Fresh-cut tomato slices tasted and smelled better when kept under active (12 to 14 kPa O2 + 0 kPa CO2) MAP at 0 or 5°C for up to 10 days, and CA at 1°C (Gil et al., 2002; Hakim et al., 2004). Yet, a small taste loss was seen during storage, correlating with Mencarelli and Saltveit (1988), who correlated the insipid flavour with a low soluble solids to titratable acidity ratio and pH. At 14 days at 5°C for earlier harvested fruit and 10 days for later harvested fruit, the limit of visual quality acceptable by consumers in pomegranate arils stored in passive MAP was achieved (López-Rubira et al., 2005). UV was found unnecessary, and antioxidant activity of arils did not differ significantly between harvest dates or during storage.

Salads and vegetables

Fruity scent in "julienne" fresh-cut carrot sticks packaged in polypropylene trays overwrapped with PVC film diminished after 5 days storage at 4°C (Lavelli et al., 2006). Carrot discs stored in high-permeability microperforated film pouches with atmospheres of 5 to 7 kPa O2 + 12 to 15 kPa CO2 maintained good aroma and flavour for 6 days at 4°C when compared to those stored in conventional polypropylene microperforated polypropylene with low permeability (Cliffe-Byrnes and O'Beirne, 2007).

NaturesealTM, however, prevented considerable surface whitening and moisture loss.Delays of 4, 8, and 12 hours at 5°C before packing fresh-cut Romaine lettuce resulted in progressively lower fermentative volatile generation, off-odor development, and CO2 damage, but increased discolouration (Kim et al., 2005). Off-flavors in fresh-cut salad savoy were rapidly developed in low OTR polyethylene film bags (8 pmol s1 m2 Pa1) by day 15 at 5°C, but the other treatments with OTR films 16.6 did not produce off-odor until day 20 or 25. (Kim et al., 2004).

After 28 days, snow pea pods stored at 5°C in MAP (5 kPa O2 + 5 kPa CO2) maintained quality and produced no off-flavors, in contrast to peas held in ambient atmospheres that were unmarketable, and under low O2 MAP (2.5 kPa +h 5 kPa CO2) that acquired minor off-flavors (Pariasca et al., 2001). Sliced mushrooms and grated celeriac stored in active MAP with high oxygen (95 kPa O2 + 5 kPa N2) retained fresh flavour and smell for 7 days at 4°C, but storage in passive MAP (3 kPa O2 + 5 kPa CO2) was limited by poor taste and development of off-odors by 3 to 4 days.

Therapies for Quality Retention that are Combination or Synergistic

Many examples of combination treatments to improve various elements of storage quality are already provided in the preceding sections. Food safety is now a major concern, and numerous research (most of which are not addressed in this chapter) have been conducted to assess the efficacy of different agents in reducing loads of microorganisms and exogenously applied foodborne pathogens in challenge experiments.

Some of these experiments also employed synergistic therapies and technological barriers. Yet, a few additional instances of conventional agents utilised without MAP, edible coatings and dips, or antimicrobials are presented.

Numerous investigations have shown that ascorbic acid, CA, calcium lactate, cysteine, or 4-hexylresorcinol are ineffective in controlling browning in long-term fresh-cut apple and pear storage. However, various combinations of these treatments with others (reduced glutathione, N-acetyl-L-cysteine) have been highly effective in controlling browning through direct action on

PPO (Rojas-Graü et al., 2008), and in some cases, no negative sensorial consequences occurred because consumer panellists could not distinguish between preservative-treated slices and control fruit (Gorny et al., 2002).

In fresh-cut 'Gala' apples, the effects of calcium ascorbate, irradiation, and MAP were studied together. Apple slices were treated with 7% calcium ascorbate before being irradiated at 0.5 and 1 kGy and stored in MAP at 10°C for up to 3 weeks (film bags). The slices softened after irradiation and storage, however the calcium treatment minimised the hardness loss (Fan et al., 2005). Overall, the combination of technologies improved microbiological food safety while preserving the fresh-cut quality of the slices. Nevertheless, no sensory assessments were carried out. Hot water dipping has recently been employed as a barrier technique to minimise microbial loads and has also been used synergistically with firmness retention applications. Dips of calcium propionate (0.9%) and calcium lactate (1.4%) applied for 1 minute at 60°C kept fresh-cut melon ('Amarillo') firm for 8 days at 5°C (Aguayo et al., 2008). When compared to the control, the calcium dips preserved cube hardness, reduced microbiological growth, and enhanced sensory quality, and there was no salty flavour in sliced melon dipped in 0.5% calcium chloride.

Many foodborne infections utilising fresh-cuts have occurred in recent years, particularly in the United States. This has generated a sense of urgency to reduce risk for both consumers and business by seeking to fast develop food safety procedures that can provide an extra degree of safety while retaining product quality.Yet, demand for very convenient fresh-cuts continues to rise, particularly in light of revitalised consumer health-conscious attitudes brought about by increased understanding and appreciation of natural phytochemicals and antioxidants in fruits and vegetables. Flavor 136 Fresh-Cut Fruits and Vegetables Advances Processing and texture are crucial components of fresh-cut fruit and vegetable quality that are difficult to quantify economically. Because commercial testing of product quality is difficult, it is sometimes considered that "if it looks good, it tastes fine."

Researchers discovered that several basic objective measurements of colour, soluble solids, weight variations or liquid leaks, and ascorbate concentration may be used to predict quality changes in fresh-cut fruits and vegetables.As previously discussed, various postharvest chemical and physical treatments intended to improve the shelf life of fresh-cut vegetables may have a detrimental impact on product flavour. Active and passive MAP, as well as securely sealed packaging, can change gaseous and flavour component metabolism, resulting in positive benefits, taste imbalances, flavour compound inhibition, or off-flavors. Sensory quality and appreciation were already issues with fresh-cuts, and this will be exacerbated when numerous synergistic treatments and antimicrobial technologies are intensively investigated in tandem with packing. This study summarises most of the recent work in this area, but falls short of providing unified answers to the taste conundrum or delivering the mythical "silver bullet" treatment(s) required to accomplish food safety, shelf life, and optimum flavour and sensory quality in stored fresh-cuts.

Because the intrinsic diversity of food, as well as all of the phases from cultivar selection to the customer, can alter flavour and sensory quality, designing relevant projects that can address all of the questions remains a difficulty. If seed businesses and researchers collaborated more often on identifying essential fresh-cut taste volatiles, cell wall correlations with texture, and understanding precursor chemical processes, speedier genetic or enzymatic regulation to address flavour and texture concerns may result. Yet, an exciting future awaits us as more information on antimicrobials and packaging (MAP) in conjunction with temperature and humidity release mechanisms, plant essential oil usage, and edible films or coatings becomes available.

Nutritional and Health Aspects of Cut Vegetables

The quality of fresh-cut vegetables is determined by two sorts of factors: visible and nonvisible. Color, texture, scent, and flavour are features of fresh-cut veggies that customers notice instantly with their senses and use to decide how acceptable or unsatisfactory a precut product is. Nonvisible qualities of fresh-cut vegetables include microbiological quality, nutritional quality, and health-beneficial aspects. Microbiological Contents146 Fresh-Cut Fruits and Vegetables Advances The quality of the processing and the lack of harmful compounds are essential elements in evaluating the safety of fresh-cut vegetables for public consumption. The quality aspects of fresh-cut vegetables that have garnered the most attention from researchers and processors in the industry are safety and sensory quality (colour, texture, fragrance, and flavour).

Because of the increased consumer interest in integrating functional foods in their diets in recent years, numerous research organisations have researched the nutritional quality and health-beneficial qualities of plant products. Functional foods, in addition to basic nutrients, contain additional compounds that, when consumed on a regular basis as part of a balanced diet, serve to maintain or improve consumers' overall health and well-being. According to this definition, plant foods can be termed functional foods in their natural state, with no need to substitute, add to, or enhance their composition. Furthermore, many of the substances utilised in the functional food business are derived from plants (phytosterols, isoflavones, lycopene, and so on).

Numerous epidemiological studies in recent years have shown that there is an inverse relationship between a diet rich in fruit and vegetables and the incidence of chronic degenerative diseases such as certain kinds of cancer and cardiovascular diseases. This impact has been related to the existence of bioactive or phytochemical components in certain foods, which have particular biological functions that create health-beneficial effects. Thus, the composition of fruits and vegetables includes not only nutrients essential to life (carbohydrates, proteins, fats, vitamins, and so on), but also phytochemical or bioactive compounds (carotenoids, phenolics, vitamins A, C, and E, fibre, glucosinolates, organosulfur compounds, sesquiterpenic lactones, and so on), whose biological activity has been studied using in vitro methods.

Vegetable Products with Little Processing

People's consumption patterns and nutrition awareness have transformed the directions of study in food technology in the twenty-first century. The similar procedure can be seen at supermarkets, which are increasingly offering refrigerated displays with bags or trays of pre-selected, cleaned, and sliced fruits and vegetables (i.e., fresh-cut vegetables). These goods provide significant benefits to modern customers in that they are simple to prepare and preserve their original freshness of colour, texture, fragrance, and flavour without sacrificing their nutritional and health-beneficial features. Fresh-cut vegetables are prepared for direct consumption by basic operations (selection, washing, peeling, stoning, cutting, hygienizing, etc.); they are wrapped in plastic film and stored cold in modified atmospheres (modified atmosphere packaging [MAP]). Customers demand meals to be nutritious, wholesome, and simple to prepare for consumption, in addition to being microbiologically safe.

Cut vegetables keep their original freshness as well as their nutritious components and the substances responsible for their healthful features since they have not been subjected to harsh processes such as heat treatments.

Fresh-cut vegetables should therefore have the same health-giving potential as the whole products from which they are derived; or the concentrations of some bioactive compounds may even be significantly improved depending on variety selection, agricultural practises, physiological state of the plant of origin, and processing stress.

Vegetable Products Including Phytochemical Compounds

The mechanics of the beneficial effects of eating fruits and vegetables, whole or cut, are not fully understood, but they appear to be related to antioxidant activity, modulation of detoxifying enzymes, stimulation of the immune response, modification of inflammatory processes, reduction of platelet aggregation, disruption of cholesterol metabolism, modulation of steroid hormone concentration and hormone metabolism, and reduction of blood pressure.

Phytochemical compounds are chemical molecules found in plant foods that give the diet physiological qualities in addition to nutritional value.

It is now recognised that oxidative stress or oxidative overload is present in a wide range of degenerative diseases, including cancer, cardiovascular disease, atherosclerosis, and neurological disorders such as Alzheimer's disease, cataract formation, macular degeneration, inflammatory processes, and the ageing process. The majority of these phytochemical compounds are antioxidants.

An antioxidant substance is one that, when present at low quantities in relation to an oxidizable substrate, slows or inhibits its oxidation. The oxidizable substrates are lipids, proteins, and DNA on a physiological level, and the antioxidants might be endogenous or exogenous (dietary).

Vitamins C and E, carotenoids, and phenolic compounds are among the most essential antioxidants found in meals. Nevertheless, other studies including antioxidant supplements, particularly -carotene, have had inconsistent outcomes.

Numerous epidemiological studies in the last 15 years (ATBC, CARET, Women's Health Study) have shown that β-carotene supplements, whether alone or in association with vitamin E, do not reduce the incidence of some kinds of cancer or of cardiovascular diseases, and that their use may even be inadvisable in individuals subject to certain physiological conditions, such as smokers.

Epidemiological investigations using fruits and vegetables or their derivatives, on the other hand, have shown health-beneficial outcomes.

Processing of Fresh-Cut Fruits and Vegetables Advances

C vitamin

Vitamin C is a water-soluble vitamin and one of the most essential micronutrients, with people getting 90% of what they need from fruits and vegetables. Vitamin C is made up of chenodiol conjugated with the carbonyl group in the lactone ring. Ascorbic acid oxidises to dehydroascorbic acid in the presence of oxygen, which has the same vitamin activity but is more unstable, allowing the activity to be easily lost by lactone hydrolysis and the creation of 2,3-diketogulonic acid. Many epidemiological studies have found a strong link between the health benefits of eating fruits and vegetables and their vitamin C levels.Vitamin C (ascorbic acid, ascorbate) is one of the most efficient and least harmful antioxidants, notably against free radicals. A low consumption of vitamin C-rich foods leads in low levels of vitamin C in the blood (0.3 mg/dL); levels between 0.8 to 1.3 mg/dL, which are considered sufficient for optimum health (Simon et al., 2001), may be obtained by people consuming 90 mg of vitamin C daily.

Vitamin C (ascorbic acid-AA + dehydroascorbic acid-DAA) concentration of fruits and vegetables varies according to species, cultivar, climatic circumstances, agricultural techniques, maturity, and, of course, postharvest management (Lee and Kader, 2000). (Tables 6.1 and 6.2). The content of vitamin C in vegetable tissues normally increases due to the action of light during plant growth and tends to decrease in the presence of nitrogen-rich fertilisers. The main source of vitamin C degradation in vegetables, however, is storage at high or improper postharvest temperatures.

As soon as the product is harvested, the vitamin C concentration begins to drop. The quantity of vitamin C that is deteriorated rises with storage temperature and duration; the amount of vitamin C that is degraded increases with storage temperature and time. Fruits with acidic pH degrade vitamin C at a slower pace than veggies with high pH.Citrus fruits, on the other hand, have been proven to be more stable in terms of vitamin C than berry fruits such as strawberries or raspberries -cryptoxanthin and -cryptoxanthin. These carotenoids, as well as lycopene, an acyclic biosynthetic precursor of -carotene, are the most widely eaten and found in human plasma.

In terms of chemical makeup, they are split into two categories: carotenes, which include simply carbon and hydrogen atoms, and xanthophylls or oxocarotenoids, which have an oxygen function, such as keto, hydroxyl, or epoxy groups, often in the terminal rings. Carotenoids have various geometric forms (cis/trans) due to the existence of double bonds, which may be transformed from one to the other by the action of light, heat, or chemical energy. As a result, carotenoid molecules are extremely sensitive to light, oxygen, and low pH. More than 600 distinct carotenoids have been found at this time, however only approximately two dozen are commonly ingested by humans.

Their physical, biological, and chemical characteristics are influenced by the system of conjugated double bonds. Thus, carotenoid compounds such as -carotene, -carotene, -cryptoxanthin, lycopene, lutein, and zeaxanthin perform important biological functions such as antioxidant activity, intercellular communication stimulation, cell growth control, intercellular differentiation of growth control, cellular differentiation (mutagenesis inhibition), and immune response modulation. Yet, lycopene, the main carotenoid in tomato and its derivatives, is the sole one.

Elements of Fresh Nutrition and Healthâ

Cut Vegetables eaten or in serum were shown to be inversely linked with the emergence of prostate cancer in a large epidemiological investigation, while others observed better outcomes with derivatives than with raw fresh tomato.High plasma levels of lycopene, lutein, or beta-carotene have also been linked to a lower risk of coronary disease, myocardial infarction, and atherosclerosis.Olmedilla et al. summarised all of these research. Carotenoid pigments are also of physiological relevance in human nutrition because several, particularly -carotene, -carotene, and - and -cryptoxanthin, are vitamin A precursors.

Carotenoid intake evaluation has been demonstrated to be difficult, owing to discrepancies in dietary composition tables and databases. Although no specific diet advice for carotenoids has been developed, some experts advocate a daily consumption of 5 to 6 mg. In the case of vitamin A, the RDA is 1,000 g retinyl Eq/day for adult men and 800 g retinyl Eq/day for adult females.

Phenolic Substances

Phenolic chemicals are secondary metabolites generated by plants that share a benzene ring in their chemical structure as well as hydroxyl groups, which are responsible for their action. Polyphenols have a broad range of forms, from simple molecules (monomers and dimers) through polymers (tannins, molecular weights greater than 500 daltons). Hydrocinnamic acids (C6-C3), benzoic acids (C6-C1), flavonoids (C6-C3-C6), proanthocyanidins (C6-C3-C6)n, stilbenes (C6-C2-C6), lignanes (C6-C3-C3), and lignines (C6-C3)n are among the most prevalent (Scalbert et al., 2005). Because many of them are pigments (responsible for the colour of grapes, cherries, plums, strawberries, raspberries, and so on), phenols have been extensively investigated for their association with the qualitative attributes of plant foods such as colour. Others generate enzymatic browning when oxidised enzymatically (polyphenol oxidase [PPO], EC 1.14.18.1), which is responsible for a high percentage of quality loss in plant foods during processing and storage. They also help to enhance the flavour and fragrance of plant meals.

Condensation of catechols to tannins, for example, results in the bitter, astringent taste of unripe apples and persimmons.Flavonoids are the most prevalent and widespread class of plant phenolics. Around 500 flavonoids have been identified and categorised into at least 10 chemical categories. Flavones, flavonols, flavanols, flavanones, anthocyanins, and isoflavones are among the most abundant in fruits and vegetables.Flavonoids have been the most extensively researched category of polyphenols in recent years. In vitro investigations have demonstrated that most present flavonoids in fruits and vegetables contain some antioxidant and radical scavenger activity to varying degrees.

Epidemiological studies link phenolic-rich foods, particularly flavonoids, to a lower risk of cardiovascular disease and various forms of cancer. Tea, spices, and grape derivatives are among the more commonly studied foods, and 152 Developments in Fresh-Cut Fruits and Vegetables Certain fruits, such as apples and berries, are also processed.

Flavonoids contain anti-inflammatory, anti-allergic, antiviral, hypocholesterolemic, and anticarcinogenic properties. It is also crucial to mention another key estrogenic action found in a group of flavonoids known as isoflavones, which increase bone mineralization as well as assist prevent atherosclerosis and some types of cancer. Onions are also a good source of the flavonol quercetin, which is responsible for the yellow colour of the pulp and the brown colour of the skin and is thought to be one of the constituents responsible for the anti-cancer and anti-cardiovascular disease benefits associated with the consumption of this product. Apples include quercetin, which is one of the components responsible for the health advantages derived from their ingestion. We would also point out the existence of glycosidated flavanones (hesperidin and narirutin) in citrus fruits, which have been linked to the health-promoting characteristics of oranges and orange juice. Red grapes, blackberries, whortleberries, raspberries, and strawberries are all high in hydroxybenzoic acids, particularly ellagic acid, which has anticancer properties Fruits and vegetables are typically good sources of flavonoids, and the more we learn about their metabolism, the more the physiological benefits of their consumption are attributed to their conjugates and metabolites rather than the intact molecule.

CHAPTER 9

BASICS OF PHYTOSTEROLS

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Around 250 distinct sterols and similar compounds have been identified as plant sterols. -sitoesterol and its 22-dehydro counterpart stigmasterol, campesterol, and avenasterol are the most frequent sterols found in fruits and vegetables. The chemical structure of these sterols is identical to that of cholesterol, with the exception of the side chain. Sterols, which are found primarily in Brassicaceae vegetables (cauliflower, broccoli) and avocado fruit, have long been known to have hypocholesterolemic effects when consumed in amounts ranging from 1 to 3 g per day, and are thus regarded as valuable allies in the prevention of cardiovascular disease. Phytosterols and their reduced counterparts, phytostanols, are hypocholesterolemic due to three metabolic actions: cholesterol intestinal absorption inhibition.Cut Vegetables 153 via competition, esterification decrease, and promotion of excretion into the gut. Phytosterols reduce total plasma cholesterol and low-density lipoprotein (LDL) cholesterol levels while having no effect on HDL cholesterol levels (Piironen et al., 2000).

Compounds of Organosulfur

The presence of sulphur atoms in the chemical structure of vegetables from the Liliaceae (onions and garlic) and Brassicaceae (broccoli, cabbage, Brussels sprouts, cauliflower) families is thought to provide health benefits. Allicin (also known as 2-propene-1-sulfinothioic acid) Ester of S-2-propenyl, when garlic is macerated or homogenised, the physiologically active molecule is thought to be CH2=CH-CH2-S(0)-S-CH2-CH=CH2). Allicin is not present in garlic until its precursor, alliin, or (+)-S-allyl-L-cysteine sulfoxide (CH2=CH-CH2-S(0) CH2-CH(NH2)-COOH, comes into touch with the enzyme alliinase when the cell membrane of the garlic is torn by cutting or maceration. Allicin is highly sensitive to heat, low pH, and organic solvents, and when processed, it produces a variety of degradation compounds, including allyl sulphide, disulfide, and trisulfide (the latter being the odoriferous factor), and allyl thiosulfinate, which is thought to be responsible for the health benefits. Allicin is also responsible for garlic's bactericidal activity. Garlic has been shown to have the following health benefits: antioxidant and free radical scavenging (a powerful inhibitor of lipid peroxidation), anti-inflammatory, anticoagulant, fungicide, antiviral (influenza, AIDS), interferon and immune system enhancement, bactericide, cholesterol reduction, anticarcinogenic, and antimutagenic properties.

Several epidemiological studies have found that a diet high in Brassicaceae vegetables (broccoli, cabbage, Brussels sprouts, cauliflower) lowers the risk of some types of cancer. This anticarcinogenic effect is attributed to the presence of glucosinolates, a group of organosulfur minority constituents, and the ability of some of its metabolites, isothiocyanates and indoles, to intervene in biotransformations catalysed by enzymes associated with the human antioxidant systems, such as glutathione-S-transferase.

The nature of all the chemicals with health-beneficial activity found in fruits and vegetables is still unknown, as are the chemical and biochemical mechanisms by which these phytochemical substances impact particular physiological functions of the organism. It is important to note that the preventive impact of a fruit and vegetable-rich diet is dependent on substances with varied chemical natures and processes, which can generate additive, synergistic, or even antagonistic effects. Certain phytochemical components, such as vitamin C or lycopene, have been clearly correlated with positive effects on the organism; in other cases, the beneficial impact has not been thoroughly shown by epidemiological research. At the moment, the biological activity of fruit and vegetable ingredients is still being studied, particularly compounds recognised for their toxic effect, such as glucosinolates and their hydrolysis.

Improvements in Fresh-Cut Fruits and Vegetables Processing Products, such as isothiocyanates, which have anticarcinogenic qualities at typical vegetable dosages. One example is the health-protective impact of carrot consumption, which has been linked to the existence of -carotene and -carotene. Some research, however, have demonstrated that the polyacetylene falcarinol, which is found in carrots and whose physiological purpose in the plant is to fight against fungal infections, has significant anticarcinogenic action in in vivo investigations in rats exposed with the carcinogen azoxymethane. Carrot consumption's anticarcinogenic effect may no longer be attributed only to carotenoid components.

The Impact of Minimal Processing on Plant Product Phytochemical Compounds and Antioxidant Capacity There is an increasing interest in the nutritional value of foods in order to understand what each individual food constituent contributes to daily nutritional needs and human well-being, as well as how food processing and preservation technologies affect its nutritional composition and health-promoting capacity. The fresh-cut fruit and vegetable sector is continually expanding as a result of customer demand for plant foodderived goods as the primary carriers of phytochemical substances responsible for acknowledged favourable health benefits from such – consumption. Furthermore, the fresh-cut fruit and vegetable sector reflects customer preferences for speedier preparation and more convenient goods with preserved nutritional content and natural and fresh colour, flavour, and texture without the use of preservatives. "Minimal processing" refers to a variety of nonthermal processing processes that assure product safety while preserving the fresh appearance of fruits and vegetables. The many phases of minimum vegetable processing (peeling, chopping, washing, sanitising) impact not only safety and sensory quality, but can also create changes in nutritional quality and health-promoting aspects of final products. The first stages (peeling, cutting, shredding) promote faster microbial degradation, physiological changes (increased respiration rate and ethylene synthesis), and biochemical changes caused by plant cell rupture and intercellular product leakage, which facilitates reactions between oxidative enzymes and their substrates. This condition causes a variety of degradation events, the most notable of which is enzymatic browning, which can cause changes in colour, texture, and flavour. Phytochemical substances, for example, can be oxidised when exposed to oxygen or light. Moreover, development of spoilage or pathogenic bacteria is enhanced at cutting areas, necessitating the use of various methods to reduce the impacts of these degenerative processes. The key element influencing deterioration of minimally processed plant products is storage temperature. Various approaches, such as the application of antioxidants, antimicrobial agents such as chlorines, and MAP, can be used to prevent the rotting of fresh-cut fruit and vegetables. Some phytochemical substances can be oxidised by antimicrobial treatments containing oxidising agents such as sodium hypochlorite.

To obtain high-quality minimally processed foods, a global processing and storage design involves a combination of diverse tactics and technologies to assist decrease degradative processes in fresh-cut vegetables. Moreover, the bioactive component content of minimally processed plant products might vary depending on genotype, environmental stress, growing circumstances, and storage and processing conditions. To achieve minimally processed plant products richer in bioactive components, cultivar and farming techniques must be chosen in conjunction with particular technology to limit the negative impacts of processing (cutting, peeling, shredding). Certain steps of the production of minimally processed plantderived goods, such as cleanliness, require special care. It is critical to minimise enzymatic and microbiological changes that may impair the stability of the phytochemical substances responsible for the nutritional content and health-promoting qualities of fresh-cut vegetables throughout these phases of the process. Processing and storage technology are chosen in the creation of novel processes to generate precut fruits and vegetables with better nutritional and health-promoting qualities based on how they improved the nutritional contents and antioxidant properties of the plant products.

The following are some findings about the influence of minimum processing on the phytochemical substances and antioxidant capabilities of fruits and vegetables.

Vitamin

The first step towards more nutritious and healthful minimally processed goods is to begin with a beginning material rich in bioactive chemicals. The vitamin C concentration of vegetables and fruits, as well as its association with genetic, maturity stage, agronomical practises, and climatic variables, has been investigated for various products and by various authors.

Significantly, there are variances in vitamin C concentration not just across types but also between cultivars. Therefore, a research on Citrus fruit types (Cano et al., 2008) discovered that orange varieties (Navel, Sweet, and Sanguine) had higher vitamin C content than mandarin variants (Clementines and Satsumes). Newhall and Navelate (Navel group) had the greatest vitamin C concentrations (64.2 and 47.8 mg/100 g, respectively), whereas Lanelate and Fukumoto had the lowest (37.5 and 39.5 mg/100 g, respectively). Oronules and Hernandine (Clementine group) had the greatest concentration (47.4 and 46 mg/100 g, respectively), whilst Satsuma (Owari, Oktisu, Avasa Pri-10, and Avasa Pri-19) had the lowest (20, 21.3, 24.9, and 25.5 mg/100 g, respectively). Substantial genotypic variations have been discovered amongst Actinidia family fruits. Kiwifruit is well-known today as a fruit strong in vitamin C. A study of eight Actinidia genotypes revealed that vitamin C content ranged from 41.7 to 1322.91 mg ascorbic acid/100 g f.w. (Du et al., 2009). Actinidia eriantha and Actinidia latifolia have greater vitamin C content (1284.87 and 1322.91 mg ascorbic acid/100 g f.w., respectively) than Actinidia chinensis and Actinidia deliciosa cultivars. Consequently, Actinidia deliciosa cv. Hayward and Actinidia chinensis cv. Xixuan had lower vitamin C levels with 63.41 and 63.41, respectively.The cutting process is another major element impacting vitamin C retention in fresh-cut veggies. For example, using a smooth knife instead of an undulated one retains 18% more ascorbic acid in iceberg lettuce.

When a mechanical cutter is used instead of a knife to chop the lettuce, vitamin C is maintained (Barry-Ryan and O'Beirne, 1999). Cutting the product may boost vitamin C loss due to an increase in surface area in contact with oxidising substances such as oxygen, which favours the action of ascorbate dehydrogenase (APX), the major enzyme responsible for vitamin C breakdown. This vitamin loss might also be attributable to the ethylene produced as a result of cutting.Another significant impact of the minimum procedure is the loss of vitamin C through the cut site into the washing water (stage following cutting). These losses may also lead to vitamin C content discrepancies between cut and complete samples. It is also critical to emphasise the impact of sanitation treatments on bioactive chemicals in plant tissues.

In the instance of broccoli, the cutting stage lowered the fresh-cut product's vitamin C concentration by 27% compared to the uncut version. The vitamin C concentration of broccoli varies depending on the section studied (stalk or floret); hence, because whole samples contained the entire stalk, their vitamin C content was 30% to 40% greater than that of sliced samples. Nevertheless, the various sanitation procedures (water and a solutions of 150 ppm sodium hypochlorite) utilised did not work (Figure 9.1).

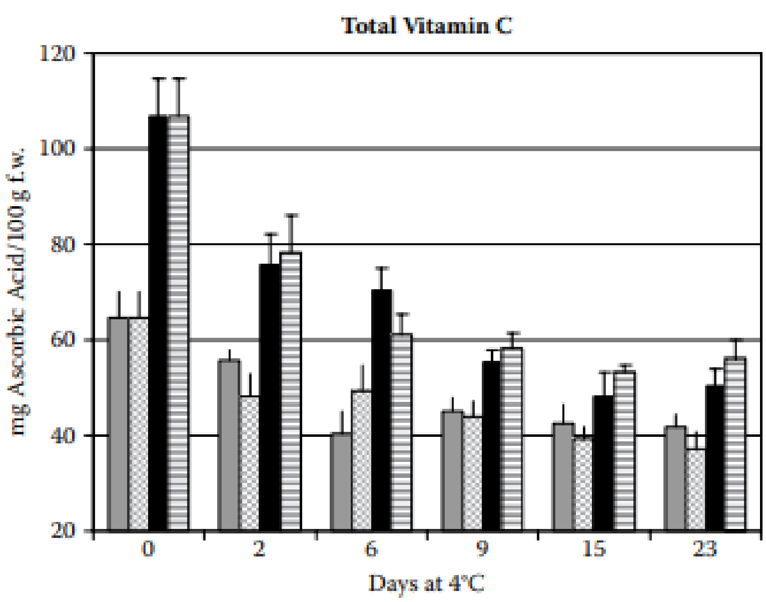

Figure 9.1 represents the Effect of minimal processing on vitamin C

Influence vitamin C content the overall vitamin C content was reduced by 28% when the equilibrium environment was reached on the second day of storage. After that, storage in a modified environment efficiently preserved the vitamin C concentration of fresh-cut broccoli for

23 days at 4oC, confirming the changed atmosphere's protective function. After 24 hours of product permanence at 20oC, these levels remained virtually stable even after the cold chain was disrupted.

Precut iceberg lettuce was used as another illustration of vitamin C stability vs other treatments. Treatments with chloride (100 mg/L), citric acid (5 g/L), lactic acid (5 mL/L), and ozonated water (4 mg/L) kept the initial levels of vitamin C in iceberg lettuce nearly constant over 8 days at 4oC, with no changes due to the specific treatment employed.In general, vegetable vitamin C concentration decreases with storage. While ascorbic acid (AA) is changed to dehydroascorbic acid (DAA) during storage, low oxygen atmospheres paired with low temperatures assist retain the original amounts of vitamin C. After 15 days of cold storage in a modified environment (5% O2 + 4% CO2), 87% of the initial vitamin C content was preserved in green pepper rings, but only 57% was retained in air (Howard and Hernandez-Brenes, 1998; Pilon et al., 2006). Yet, in other circumstances, storing the sliced vegetable in air produces greater outcomes. Vitamin C levels, for example, were maintained or even increased (16% to 18%) in different potato types following Total Vitamin C 20 40 60 80 100

The effect of minor processing on vitamin C levels in broccoli florets packed at 4oC in a slightly changed environment (16% O2 + 4% CO2). In rare circumstances, vitamin C levels are lowered in an environment high in carbon dioxide (10% to 30% CO2). This is owing to the CO2's detrimental effect, which promotes cytoplasmic acidification and, as a result, oxidative damage with increased ascorbate oxidase activity. Nutritionally, CO2-rich environments may not be optimal for maintaining early vitamin C levels in some crops. When the concentration of dehydroascorbic acid in the atmosphere rises, so does the concentration of carbon dioxide (DAA). It has been observed that ascorbic acid (AA) is more sensitive to degradation by CO2-rich atmospheres than dehydroascorbic acid (DAA), as AA concentration tends to decrease in these atmospheres while DAA tends to rise. It has been proposed that CO2-rich environments can boost AA oxidation (Agar et al., 1997). The increase in the percentage of DAA associated with the loss of total vitamin C has thus been linked to oxidative stress, a situation in which AA is required to neutralise the reactive oxygenated species (ROS) produced, resulting in the conversion of AA to DAA followed by degradation of the latter to products lacking biological activity.

For example, it was found that spinach stored in a modified environment (6% O2 + 14% CO2) preserved more vitamin C than spinach stored in air, despite the fact that the quantity of dehydroascorbic acid was higher in the modified atmosphere (Gil et al., 1999). Total vitamin C was preserved better in air than in the modified environment in sliced Swiss chard, which contains just DAA. Nutritionally, modified or controlled atmospheres with more than 10% CO2 may not be adequate for preserving initial vitamin C levels in particular fruits, such as little processed kiwi. For example, after 12 days at 0oC, the vitamin C content of kiwi slices held in a controlled environment with 5%, 10%, and 20% CO_2 decreased by 14%, 22%, and 34%, respectively.

Some little processed fruits, such as strawberries or persimmons, on the other hand, kept their original vitamin C levels almost unaltered when held at 0oC for 8 days in controlled atmospheres with a CO_2 content of 12%. Many studies have been conducted to determine the influence of minimum processing on the vitamin C content of fruits. Gil et al. (2006) studied the influence of peeling and cutting procedures on the vitamin C content of various fruits preserved in air for 9 days at 5oC. They discovered that the reaction of vitamin C content to stress generated by the preparation procedure (peeling and chopping) varied depending on the kind of fruit. For example, fresh-cut pineapple chunks stored at 5oC for 6 days showed a significant decrease in ascorbic acid and an increase in dehydroascorbic acid; the final result was a significant (10%) increase in total vitamin C content of fresh-cut pineapple compared to whole unprocessed pineapple stored in the same conditions. There were no significant variations in vitamin C content between fresh-cut and whole strawberries; in both products, there was a progressive rise in vitamin C content, so that at the conclusion of storage at 5oC, the final concentration was 17% greater than at the start. Diced mango, on the other hand, retained its flavour.

The initial vitamin C concentration remained unchanged after 6 days of storage at 5oC, with no notable variations from the whole fruit. Eventually, the vitamin C content of fresh-cut kiwi was 7.5% lower than the whole product at the end of storage. The type of cut used may also alter the nutrient content of fresh-cut fruits and vegetables. Argaosa et al. (2008) investigated the impact of several cut types (cube, parallelepiped, cylinder, and sphere) on the quality of papaya cv. 'Sunrise' stored at 4oC for up to 10 days. In this study, cube-shaped fresh-cut papaya retained more ascorbic acid than other cut kinds being sliced in the cylinder, resulting in an 18% reduction in ascorbic acid concentration after a 10-day shelf life at 4oC. Artés-Hernandez et al. (2007), on the other hand, reported that wedges, slices, and half slices of fresh-cut lemon goods ('Lisbon') maintained for 10 days at 0, 2, and 5oC showed high ascorbic acid retention (85%), with no changes identified related to cut type.

Oranges are widely consumed across the world, and as such, they are regarded as the primary dietary source of vitamin C. Minimally processed orange segments are a novel product developed to help some consumers (children, the elderly and infirm, etc.) accept it or to service the institutional catering industry (schools, hospitals, work canteens, hotels, etc.). Manual peeling and segmenting of oranges, packaging in a slightly modified atmosphere (19% O_2+ 3% CO_2), and low-temperature storage (4oC) produced no significant changes in vitamin C concentrations in orange segments after 10 days in chilled storage, while a 24% decrease in AA concentration was observed (Crespo et al., 2005). Piga et al. (2002) found that after 12 days of storage at 4oC under MAP conditions, minimum processing resulted in a 13% reduction in AA content in segments of mandarin cultivars. Del Caro et al. (2004) discovered a reduction in ascorbic acid ranging from 1.63 to 5.10 mg/g dry matter in 'Minneola' tangelo and 'Salustiana' orange segments held at 4oC for 12 days, while no alterations were reported in 'Shamouti' orange segments. Other citrus fruits, such as fresh-cut lemons prepared as wedges, slices, and half slices and kept for 10 days at 0, 2, and 5oC, showed good vitamin C retention (approximately 85% ascorbic acid and 15% dehydroascorbic acid).

Vitamin C content in minimally processed citrus products is reasonably constant and does not change considerably from whole oranges, lemons, or mandarins. The vitamin C concentration given by fresh-cut citrus fruits stored in MAP for up to 12 days is comparable to that supplied by an equivalent amount of newly processed citrus fruit.To suit customer demands, minimally processed fruits require a mix of innovative preservation procedures capable of maintaining the safety and quality of the fruit products for a longer storage duration. In this regard, edible coatings might be used to extend the shelf life of fresh-cut fruit packaged under MAP by lowering moisture and solute losses, gas exchange, respiration and oxidative reaction rates, and physiological disorders (Rojas-Graü et al., 2008). Oms-Oliu et al. investigated the impact of polysaccharide-based edible coatings such as pectin (2% w/v), gellano (0.5% w/v), and alginate (2% w/v) with antibrowning compounds such as N-acetylcysteine and glutathione on antioxidant contents of fruits such as pears (2008a). The application of polysaccharide-based edible coatings containing N-acetylcysteine and glutathione considerably decreased vitamin C loss of fresh-cut pears at 4oC for up to 11 days (loss up to 18%) compared to untreated or coated portions without antioxidants (losses ranging from 32% to 48%). Antioxidants inhibited oxygen diffusion, preserving the vitamin C content of fresh-cut pears.Although the kind of packing and storage temperature are determining variables rather than first processing stages, initial processing activities do not appear to have a major influence on vitamin C loss in fresh-cut fruits and vegetable.

Phenolic Compounds

Mechanical damage is sustained by plant tissue as a result of peeling and cutting, which increases phenolic synthesis, which is associated with an increase in activity of the enzyme phenylalanine employed to quantify (PAL; EC 4.3.1.5), a physiological response of the plant tissue to mechanical damage in order to reduce water loss and pathogenic microorganism attack. The increased activity of phenylalanine ammonio-lyase implies that phenol-synthesizing processes are activated in response to specific signals, such as the presence of ROS generated by stress.

The amount of total phenol concentration that increases as a physiological reaction to mechanical stress varies depending on the plant tissue. For example, in certain items, such as lettuce, carrot, celery, or sweet potato, total phenols increased significantly (81%, 191%, 30%, and 17%, respectively), but in others, such as courgette, radish, or red cabbage, total phenols decreased (26%, 15%, and 9%, respectively). This is due to a balance between the creation of phenols and their use in the synthesis of insoluble phenols (lignin and suberin) or in oxidative polymerization products (enzymatic browning).

When the chopped vegetable is kept in a modified or regulated environment, the accumulation of phenolic chemicals and the increase in phenylalanine ammonio-lyase activity are suppressed. Significant increases in soluble phenolic acids such as chlorogenic acid in carrots and caffeic acid in Lollo Rosso lettuce have been observed after cutting and during the early days of storage in air at 4 to 5oC, which has been associated with an increase in the enzyme phenylalanine ammonio-lyase. In contrast, phenolic acid production was stopped in a CO2-rich (12% to 30%) modified environment with or without O2 (2%), or in an atmosphere containing 99% N2, and concentrations remained constant or even decreased towards the end of the storage period (Gil et al., 1998a; Reyes et al., 2007). Flavonoids in some plants, such as red leaf lettuce, exhibit similar characteristics, however mechanical damage at the cutting stage impacts flavonoids less than phenolic acids (Ferreres et al., 1997; Gil et al., 1998a). Some plants, such as Swiss chard (Beta vulgaris cycla), had a distinct impact, with the content of flavonoids increasing over the period of 8 days.

Graph 6.6 Processes triggered inside the plant cell as a result of mechanical injury to plant tissue. Reactive oxidative species (ROS) and antioxidant molecules are involved. Ks and Kd are constants of synthesis and phenolic degradation rates, respectively. The amount of antioxidant capacity that increases after injury varies on the kind of fruit or vegetable tissue. Food Chemistry 101, 1254-1262.

Breakthroughs in Fresh-Cut Fruits and Vegetables After storage at 6oC in both air and a modified environment (7% O2 + 10% CO2) (Gil et al., 1998b), or spinach, where the flavonoid compounds were constant after 7 days of storage at 8oC in both air and a modified atmosphere (Gil et al., 1998b) (Gil et al., 1999). A study on cut celery found an increase to twice the initial concentrations of luteolin and apigenin, flavones that account for 44% of the flavonoids present in this vegetable, 6 hours after processing, and a recovery of the initial concentrations after 24 hours in 0oC storage. This suggests that stress affects flavonoid production as well, but that equilibrium is restored more rapidly than in the case of phenolic acids. CO_2-rich atmospheres appear to be suitable for maintaining flavonoid compound concentrations, but how useful they are for augmenting antioxidant phenolic acid concentrations in order to improve the nutritional and health-beneficial properties of cut vegetables depends on the type of vegetable concerned.

In general, the effect of cutting on phenolics has been widely studied, but little is known about the impact of hygienizing procedures. While broccoli florets had 11% higher total phenols than whole broccoli, the hygienic treatment (a solution of 150 ppm sodium hypochlorite) had no effect on total phenol content. It was discovered that a modified environment might preserve phenolics during refrigerated storage, where levels remained stable for 21 days.Different hygienizing technologies, such as ionising radiation, can boost overall phenol content and concentrations of possible antioxidant components in some crops, such as Chinese cabbage by choosing the right treatment settings. Whereas 0.5 kGy radiation increases total phenol content, 1 kGy radiation produces a considerable drop in the same parameter. This increase in phenolic production at 0.5 kGy is likely related to the generation of free radicals during irradiation, which function as a stress signal, activating antioxidant systems in plant tissue.

Current research has revealed that novel hygienic systems, such as UV-C with germicide activity (265 nm), are capable of increasing the quantities of some physiologically active polyphenolics, such as anthocyanins and the stilbene known as trans-resveratrol, in red grape. Most studies on the effect of initial minimal processing operations (peeling and cutting) on anthocyanins in vegetables like sweet potato, red cabbage, or 'Lollo Rosso' lettuce have found no significant changes, and the small decline observed has been linked to oxidation mechanisms catalysed by the enzymes polyphenol oxidase and lipoxygenase. The effect of air or modified atmospheric storage on anthocyanins is also dependent on the kind of vegetable. For example, the content of anthocyanins in green lettuce leaves held in air was unaffected, while it was significantly decreased under a modified environment. Nevertheless, in red-leaf lettuce ('Lollo Rosso,' which has a higher starting anthocyanin content, the degradation was greater in the modified atmosphere than in air, indicating that modified atmosphere technology would not be a good tool for preserving anthocyanin levels in red tissues.Nevertheless, it was recently found that hygienizing treatments with ultraviolet radiation (UV-C, 254 nm, 30 to 510 W) substantially boosted anthocyanin concentrations in anthocyanin-rich foodstuffs such as red grapes

Onion is distinguished by high levels of the flavonol quercetin (557 mg/kg f.w.), which vary according to variety. Neither cutting nor washing in a solution of 150 ppm sodium hypochlorite had a significant effect on the quercetin content of cut onion in a modified atmosphere during the first few days of storage, but after 30 days at 4oC, the samples treated with the sodium hypochlorite solution had approximately 20% more quercetin than samples washed with water Generally, packageing in a modified environment had a protective impact on quercetin concentrations, which remained nearly unaltered after 30 days in storage.

Fruits are similarly high in phenolics. Red grapes, blackberries, whortleberries, raspberries, and strawberries are all high in hydroxybenzoic acids, particularly ellagic acid, which has anti-cancer properties.Citrus fruits are high in glycosidated flavanones (hesperidin and narirutin), while the majority of fruits (apples, pears, peaches, strawberries, plums, melons, and others) are high in flavonols like quercetin and kaempferol. Lastly, anthocyanins may be found in berries including strawberries, raspberries, blackberries, and whortleberries, as well as other foods like cherries.

The magnitude of the rise in total phenol content as a physiological reaction to mechanical damage to plant tissue generated by peeling and cutting varies depending on the kind of fruit. The total phenol content of fresh-cut pineapple, for example, was rather constant and did not alter considerably from that of whole pineapple held in the same settings (9 days in air at 5oC) Similar behaviour was found in mango and melon, where total phenols remained generally steady for 9 days at 5oC, however the amount was much reduced towards the end of storage in the case of sliced melon. There was no observable effect attributable to cutting in strawberries, which contain high concentrations of phenolics (total phenols 60 mg/100 g f.w.), mostly anthocyanins (pelargonidin-3-glucoside) and flavonols (quercetin glycosides and kaempferol derivatives); total phenols, flavonoids, and anthocyanins remained stable throughout storage at 5oC.

The concentrations of phenolics are dramatically influenced by high-CO2 (12% to 30%) modified atmospheres. When sliced fruit is kept in a modified or regulated environment, for example, phenolic compound formation and increased phenylalanine ammonio-lyase activity are suppressed (Reyes et al., 2007). Flavonoids act in a similar manner. A high-CO2 (>20%) environment, for example, induced the destruction of strawberry anthocyanins, particularly in the inner tissue. Color deterioration was found during refrigerated storage of strawberries in a controlled environment, which was linked to a decrease in the activity of phenylalanine ammonio-lyase, the enzyme involved in anthocyanin production.

In general, high-O2 environments in the package headspace of fresh-cut fruits and vegetables reduced total phenolic content significantly. Under 2.5 kPa O2 + 7 kPa CO2 and 10 kPa O2 + 7 kPa CO2 atmospheres, the phenolic content was around 16 to 20 mg gallic acid 100 g f.w., whereas concentration was 13 mg gallic acid 100 g f.w. under 70 kPa O2. Total phenolic content was best preserved or enhanced in fresh-cut melon held at 2.5 kPa O2 + 7 kPa CO2 for up to 11 days at 4oC under these circumstances. The 2.5 kPa O2 + 7 kPa CO2 environment produced more phenolic compounds than higher oxygen content atmospheres (10, 21, 30, and 70 kPa O2), which might be attributed to increased oxidative stress caused by too-low O2 and high CO2 concentrations inside the package). During minimum processing, wounding may promote phenylalanine ammonio-lyase (PAL, E.C. 4.3.1.5) activity, resulting in more phenolic compound synthesis. PAL activation might be evoked by increased ROS. Fresh-cut pear was kept in this environment (2.5 kPa O2 + 7 kPa CO2) phenol content more than 70 kPa O2 ambient conditions after 14 days of storage at 4oC (Oms-Oliu et al., 2008b). Cocci et al. (2006) found that fresh-cut apples stored in air packaging (21 kPa O2) degraded more quickly than those stored in low oxygen environments for example (5 kPa O2 + 5 kPa CO2).This phenomena might be caused by the rapid oxidation of phenolic chemicals on the cut surface when they come into contact with the O2 in the package headspace.

Increased activity of the enzyme phenylalanine ammonio-lyase (PAL) in fresh-cut veggies was also detected in the flavonol compounds of fresh-cut citrus fruits such as oranges as a result of the stress caused by limited processing processes.

The first peeling and cutting operations had no effect on the concentration of total glycosidated flavanones, however storage in a slightly changed environment at low temperatures (4oC) induced an increase in flavanone concentration.A rise in hesperidin in minimally processed orange segments after 12 days at 4oC was considerable (Crespo et al., 2005). Quercetin, another flavonol component, raised the initial amount in fresh-cut pear by more than threefold after 14 days of storage at 4oC in atmospheres with high (70 kPa) and low oxygen content (2.5 kPa O2 + 7 kPa CO2).

Browning of cut surfaces is a major issue in the growth of fresh-cut fruits. The disruption of fruit cellular compartmentation allows polyphenol oxidase to oxidise phenolic substances (PPO). Antioxidant substances such as N-acetylcysteine and glutathione are utilised to prevent enzymatic browning. These thiol-containing natural substances react with o-quinones.Colorless adducts or o-diphenols are formed during the first step of enzymatic browning processes. The usage of these antioxidants slows the breakdown of some phenolic acids, such as chlorogenic acid, which occurs in fresh-cut pears. Mechanical injury to plant tissue produced by peeling and cutting boosts phenolic compound production in fresh-cut fruits and vegetables.The kind of packaging and storage temperature, as well as the chemical structure (phenolic acids or flavonoids), are important determinants in the preservation of phenolic compounds.

CHAPTER 10

SUBSTANCES CONTAINING CAROTENOIDS

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Carotenoid compounds in fruits and vegetables do not generally change significantly as a result of minimal processing, and the changes that do occur have been linked to oxidation mechanisms catalysed by the enzymes polyphenol oxidase and lipoxygenase, as well as the presence of light, oxygen, and low pH (Reyes et al., 2007). Chilled storage has been shown to produce a persistent time-dependent drop in carotenoid retention in minimally processed vegetables, whereas atmospheres with a low oxygen content and a high proportion of nitrogen or carbon dioxide promote carotenoid retention. At the same storage circumstances, packing in a modified environment retains original carotenoid concentrations in cut vegetables, but packaging in air resulted in some degradation. For example, after 15 days of cold storage in a modified environment (5% O2 + 4% CO2), almost 90% of the carotenoid components were preserved in green pepper rings, but only 52% were retained in air (Howard and Hernandez-Brenes, 1998; Pilon et al., 2006). The same is true for fresh-cut carrot, where the carotenoid content was maintained constant throughout storage in a nitrogen-enriched environment (90% N2 + 5% CO2) (Alasalvar et al., 2005).

Minimally treated fruits typically reach the end of their shelf life before their carotenoid chemicals degrade significantly (Wright and Kader, 1997). The effect of peeling and cutting on carotenoid component concentrations will vary depending on the kind and species of fruit (Gil et al., 2006).Carotenoid compound concentrations in whole pineapple (cv. 'Tropical Gold') (250 g/100 g f.w.) and whole mango (cv. 'Ataulfo') (3,000 g/100 g f.w.) showed no significant change after 9 days of storage in air at 5oC; however, levels in pineapple and mango chunks dropped significantly (25%) after 3 and 9 days, respectively. The carotenoid content of melon (cv. 'Joaquin Gold') decreased as a result of peeling and cutting.

Although atmospheres with a low oxygen content and a high proportion of nitrogen or carbon dioxide encourage their preservation in fresh-cut vegetables, chilled storage produces a prolonged time-dependent drop in carotenoid component concentrations. Total antioxidant carotenes in Navelina oranges, for example (142.78 g/100 g f.w.)—relative contents The early phases of minor processing (peeling and cutting) to generate orange segments did not significantly affect the levels of 40% lutein, 27.5% -cryptoxanthin, 20% zeaxanthin, 5% -carotene, 4.6% -cryptoxanthin, and 3% -carotene. During 12 days of cooled storage in a customised refrigerator.

Carotene concentrations increased significantly in both whole unprocessed oranges (stored at 8oC) (89%) and fresh-cut orange segments (stored at 4oC) (23%). This is due to the production of carotenoid molecules during refrigerated storage, which has been well described in the literature. This suggests that eating orange segments that have been little processed and kept at 4oC for up to 12 days provides a similar concentration of antioxidant carotenoids as eating freshly cooked orange (Crespo et al., 2005).Freshcut tomatoes kept their initial lycopene concentration after 21 days at 4oC due to lycopene synthesis triggered by ripening and limited oxidation of this carotenoid due to low oxygen availability in the package headspace.

ncreased antioxidant activity (measured using the ABTS+ or DPPH radical scavenging methods) was found in tissues of various vegetables in response to mechanical stress (peeling and cutting); this has been linked to an increase or decrease in phenolic compound concentrations more than vitamin C concentration, as reported in numerous publications on minimal vegetable processing. Many studies have demonstrated that its phenolic components confer antioxidant ability (Proteggente et al., 2002), and that this capacity is one of the primary reasons why greater fruit and vegetable diet has been suggested as good to health (Prior and Cao, 2000). As a result, we may conclude that the mechanical damage generated by the peeling and cutting operations might improve the health characteristics of specific vegetables.

It is crucial to highlight that the methodology employed to assess antioxidant activity has an impact on the results. For example, it was discovered that in cut tomato packaged under a highly permeable film suitable for microwaving (Magnetron), the antioxidant capacity, measured in lipophilic extracts as the ability to scavenge the radical ABTS•+, remained unchanged during storage, whereas the antioxidant capacity measured in hydrophilic extracts declined with time in storage at 5oC in comparison to the antioxidant activity of whole tomato. Hence, little processing appears to diminish tomato's ability to provide hydrophilic antioxidants to the diet. This demonstrates the impact of processing on a health-beneficial feature of vegetable products, in this case antioxidant capacity.

Carotenoids in Total

Whole, peeled segments

Total carotenoids in minimally processed orange products (whole-peeled and segments) held in a modified environment. The antioxidant activity of vegetable products is often influenced by minimal processing to the degree that it modifies the bioactive ingredient responsible for that activity—in most cases, phenolic compounds and vitamin C. For example, the antioxidant activity of celery after 24 hours at 0oC in a modified environment showed no significant differences from the control, and the amounts of luteolin and apigenin, flavones accounting for 44% of celery's flavonoids, were unchanged (Via and Chaves, 2007). A similar pattern was found in fresh-cut tomato, where no changes in antioxidant capacity were identified, possibly due to the preservation of phytochemical components (lycopene, vitamin C, and phenolic compounds) during minimum processing processes, packing, and refrigerated storage.

The antioxidant capacity of fresh-cut spinach was diminished when ascorbic acid was oxidised to dehydroascorbic acid during refrigerated storage in a changed environment. The reduction of antioxidant ability in this example was linked to a decrease in ascorbic acid content (Gil et al., 1999). The decline in antioxidant capacity in fresh-cut mandarin, fresh-cut pears, and fresh-cut melon after storage has been linked to bioactive component depletion.

The hygienizing processes employed to achieve a safe fresh-cut vegetable product might also affect their ability to block free radicals. If the right treatment settings are chosen, the combined action of ionising radiation and changed atmospheres can boost antioxidant activity in specific goods, such as Chinese cabbage (Brassica rapa L.). Treatment with 0.5 kGy radiations boosted the antioxidant capacity of chopped Chinese cabbage, but treatments with more than 1 kGy had the reverse effect. Hence, irradiation may be regarded appropriate for increasing antioxidant activity in cut vegetable products.

Glucosinolates

Isothiocyanates, which are formed by the hydrolysis of glucosinolates in Brassicaceae plants (broccoli, cabbage, Brussels sprouts, cauliflower), have been proven in epidemiological studies to reduce the incidence of various types of cancer (colon and lung) (Lund, 2003). The quantity of glucosinolates in plant tissue, their conversion to isothiocyanates, and the bioavailability of isothiocyanate metabolites are all associated to anticarcinogenic activity. At the initial stage, glucosinolate content varies according to genetic and environmental variables (cultivars, temperature, light, growing system, fertilising procedures, postharvest storage and processing). Hence, growing broccoli in hydroponic circumstances and applying a stress element (i.e., NaCl) during head induction and during growth might be favourable for glucosinolate enrichment (Moreno et al., 2008). In general, cutting plants of the Brassicaceae family reduces the concentration of glucosinolates by the action of the enzyme myrosinase (Leoni et al., 1997), resulting in a variety of hydrolysis products, the most important in terms of biological activity being isothiocyanates. For example, after 6 hours, the initial content of glucosinolates (62 mol/100 g f.w.) in broccoli florets had reduced by 75%. Only 50% of them were hydrolyzed to isothiocyanates at 25oC. Nevertheless, no significant changes were found between storage at room temperature and cold storage (4 to 8oC); in both cases, the initial content of glucosinolates decreased by 27% in 7 days.

Several authors discovered that removing a portion of the stem during the processing of the fresh-cut broccoli product resulted in a statistically significant increase (30% to 40%) in glucosinolate content.This increase in extracted glucosinolates could be attributed to the induction of glucosinolate synthesis in response to cutting, or to an increase in the percentage of inflorescences in the cut product, where the glucosinolates are present in significantly higher concentrations despite being distributed throughout the plant.There has been limited investigation into the effect of hygienizing therapies on glucosinolate integrity, however they do not appear to have a significant impact on storage. For example, a hygienizing treatment with or without sodium hypochlorite had no effect on glucosinolate levels in cut broccoli florets held at 4oC for 23 days

In general, controlled atmospheres (6% CO_2 + 2% O_2) combined with chilling at 4oC have been reported to extend the shelf life of chopped broccoli compared to air storage, owing to a reduction in respiration rate. In these conditions, it is feasible to manage chlorophyll breakdown and, as a result, the emergence of yellowing as a marker of senescence in these goods. Several writers suggest CO2 Total Glucosinolates 0 5 10 15 20 25 30 35 026 9 15 23 Days at 4C Micromoles/g d.w.

The effect of minimum processing on total glucosinolates in broccoli florets grown at 4oC in a slightly changed environment (16% O2 + 4% CO2). Minimal processing has a protective impact on the bioactive components of broccoli (Brassica oleracea L. var. italica) during refrigerated storage and following cold chain breakage. Abstracts of the Fifth Iberoamerican Conference on Postharvest and Agricultural Exports.

Cut Vegetable Nutritional and Health Aspects 175 concentrations less than 8% and O2 concentrations more than 2% to avoid the production of unpleasant smells within the packing (Bastrash et al., 1993). Total glucosinolates (15%) decreased nonsignificantly during storage under a changed environment. Other scientists, however, found a 71% decrease in total glucosinolates after storing broccoli for 7 days at 4oC in a comparable environment. Healthy Qualities of Minimally Processed Vegetables Research on the effect of several "minimum processing" technologies, such as high hydrostatic pressure, demonstrate that the healthy characteristics of fruit and vegetable derivatives remain unaltered after processing.

These included human intervention trials to investigate parameters related to the effects of these products' consumption, such as phytochemical compound bioavailability (vitamin C, carotenoids) and biomarkers for oxidative stress (isoprostanes) and inflammation (C-reactive protein [CRP] and prostaglandin E2 [PGE2]). These research revealed that high hydrostatic pressure processing preserves the bioactive components and health benefits associated with fruit and vegetable intake.

There are also human intervention research on the effect of minor vegetable processing (cutting, hygienizing, modified-atmosphere packing) on phytochemical component bioavailability (carotenoids, tocopherols, flavanones). For example, the various methods used to manufacture fresh-cut broccoli (cutting, washing with a 150 ppm sodium hypochlorite solution, modified-atmosphere packing, and 9 days at 4oC storage) had no effect on the bioavailability of carotenoid components or tocopherol in the product (Granado-Lorencio et al., 2008). Another research using minimally processed orange segments maintained in a modified environment at 4oC found that after 7 days of consumption, levels of flavanones, hesperidin, and naringenin had dramatically risen, maintaining constant until the end of the study (De Pascual-Teresa et al., 2007). This suggests that taking 200 g of minimally processed orange segments daily is adequate to enhance plasma levels of flavanones and their metabolites, accounting for the positive impact of consuming flavonoids from this family as proven in many epidemiological studies (Erlund, 2004).

To summarise, particular processing parameters (cutting, hygienizing procedure, modified environment, storage temperature) must be chosen for each fruit or vegetable in order to obtain a safe fresh-cut product with excellent nutritional quality and intact health benefits. The data on the beneficial effect of modified-atmosphere packaging combined with chilled storage on certain phytochemical compounds are generally contradictory; however, the concentrations of certain phytochemical compounds (carotenoids, vitamin C, and polyphenolics) and antioxidant activity are retained or even increased in some fresh-cut vegetable products. In general, the concentrations of phytochemicals 176 Advances in Fresh-Cut Fruits and Vegetables Fresh-cut (minimally processed) fruits and vegetables or combinations have similar processing ingredients, nutritional content, and beneficial characteristics to the entire veggies from which they are obtained.

Nutritional Declarations and Food Health Properties Regulations

More scientific studies (in vitro and in vivo) are needed to reliably determine the effect of minimal processing on the nutritional and bioactive substances in vegetable products, as well as the health effects produced by their consumption, in response to the new regulations governing nutritional labelling and application to minimally processed foods. This would make it easier to create "nutritional profiles" for health experts and food technologists to enlighten customers with credible nutritional and health claims based on authentic scientific studies.

The Codex Alimentarius Commission was established to carry out the joint Food and Agricultural Organization (FAO)/World Health Organization (WHO) food standards initiative. The Codex recommendations on nutrition labelling are based on the idea that no food may be represented or presented in a deceptive or misleading manner (Codex Alimentarius Commission, 1992). The Codex Guidelines on Nutrition Labeling include provisions for voluntary nutrient declarations as well as the calculation and presentation of nutrient information that is, it establishes general principles to be followed while leaving specific declarations to national regulators.

With this obligation, several governments have developed distinct standards for food nutrition and health claims. According to the United States Food and Drug Administration (FDA), the organisation in charge of food regulations, nutritional labelling is necessary for processed goods (http://www.cfsa.fda.gov/label.html), while it is optional for fresh-consumed items (71 FR42031 of August 2006). Since 1990, the FDA has authorized a comprehensive set of guidelines governing nutrition and health claims for foods, which are revised on a regular basis. Labeling claims fall into three categories: health, nutrient content, and structure/function. Each of these types of claims is allowed by the FDA via the responsible body (Office of Nutritional Products, Labeling, and Dietary Supplements) of the Center for Food Safety and Applied Nutrition (CFSAN).

In this area, European legislation falls considerably behind that of the United States. The new Community Regulation on nutritional and health claims made on foods (Regulation (EC) 1924/2006 of the European Parliament and of the Council of 20 December 2006), which has been in force since 19 January 2007 and is mandatory since July 2007, is based on the requirement that nutrition and health claims made by the food industry be true and state the scientific basis on which they are founded. Consumer protection is an essential component of the new regulation, and it is ensured by making it mandatory to market only safe foods with proper labelling to ensure that nutrition and health claims are based on real scientific evidence and not on misleading, exaggerated, or scientifically baseless messages.

To ensure the veracity of food industry claims, for example, the new regulation requires that substances or products for which such claims are made have been shown to have a beneficial nutritional or physiological effect by means of internationally accepted scientific tests, which will be regulated in Spain by the Spanish Food Safety and Nutrition Agency (Agencia Espaola de Seguridad Alimentaria y Nutrición/AESAN). Furthermore, the bioactive ingredient about which the claim is made must be present in adequate concentrations, or missing, or present in tiny enough quantities, in the finished product to provide the stated nutritional or physiological impact. This bioactive component must also be present in high enough quantities to cause the claimed effect in a quantity of food that can be taken as part of a daily diet and be digested by the body after the food is consumed. As a result, phrases such as "light," "low-fat," "reduces cholesterol," or "high fibre content" may only be used on product labels provided the manufacturers/distributors follow the regulations. To be allowed to claim that a food is "lowsugar," for example, it must be assured to contain no more than 5 grammes of sugar per hundred grammes of fresh product.

The legislation states that nutrition and health claims may only be made in three categories based on these criteria:

A "nutrition claim" or "content claim" is one that states, suggests, or implies that a food has specific beneficial nutritional properties due to the energy it provides or the nutrients or other substances it contains or does not contain. A "health claim" is one that asserts, implies, or indicates that there is a link between a food categories, a food, or one of its ingredients and health (for example, "reduces cholesterol"). A "reduction of disease risk claim" is one that asserts, implies, or indicates that consuming a food category, a food, or one of its parts significantly decreases a risk factor in the development of a human illness (for example, "reduces the risk of cerebral ischemia or strokes"). The legislation establishes the notion of "nutrient profiles" to broadly establish and limit the composition of a product as the framework for making claims.

The rule includes the health authorities of all European Union member states in terms of implementation and monitoring. The European Food Safety Authority (EFSA) plays a critical role in examining the scientific underpinnings for claims and developing "nutrient profiles." In Spain, the EFSA collaborates with the AESAN (Ministry of Health and Consumer Affairs), which will be in charge of enforcing the rule in collaboration with the autonomous communities and will be the authority tasked with investigating claims made by Spanish producers.

Fruits and Vegetables for the Fresh-Cut Processing Industry

Fruits and vegetables are a natural gift that pleasure people of all ages. They have a variety of tastes and textures and include the majority of the nutrients needed for optimal health and fitness. Fresh produce intake is widely advised all over the world; nevertheless, consumers currently have limited time for food preparation. This has resulted in the growth of the fresh-cut fruits and vegetables industry, since they provide good and convenient ready-to-eat product with the benefits of fresh produce.

Fresh-cut fruits and vegetables are made up of live cells that naturally decay and deteriorate with time and are influenced by all pre- and postharvest handling, processing, and storage procedures. Respiration and ethylene production rates, as well as colour, flavour, and texture, fluctuate in response to physical damage caused by cutting procedures and the activity of unwanted microbes. The quality attributes of the fruits and vegetables used as raw materials for processing have a significant impact on the final quality and shelf-life of fresh-cut products; therefore, it is critical to identify and comprehend relevant changes for specific products and how they are influenced by handling, processing, and storage.

Produce for the fresh-cut business should be resistant to processing and retain their characteristics with minimal fluctuation for as long as feasible. This chapter focuses on the fruits and vegetables handling and conditioning needs for fresh-cut product processing.

Fresh Fruits & Vegetables in Good Condition

The quality of fresh fruits and vegetables is supposed to be maintained during handling, storage, processing, and distribution. Although quality standards differ from product to product, they are often related with inherent food attributes such as visual appearance, texture, flavour, nutritional value, and safety problems during field production, handling, and processing. Shape, size, colour, gloss, uniformity, and the absence of wilting, browning, and decay signs all have a big impact on product selection for processing; they provide hints about the stage of maturity, freshness, and predicted process output.

Texture attributes collect structural aspects of the product as well as associated sensory properties felt when the product is eaten. The shapes, chemical composition, adhesive and cohesive forces between cells, and how they are affected by turgidity, maturity stage, and other variables of fresh fruits and vegetables cells and tissues are complex, resulting in a wide range of responses to force stresses during handling and processing.

Texture is defined by a set of parameters for particular properties such as firmness or hardness, fracturability, adhesiveness, gumminess, crispiness, fibrousness, juiciness, flexibility, and others, the relative importance of which depends on the product and its intended function. When fresh-cut produce is processed, the mechanical response of intact produce is impaired due to wounded cells and tissues, size decrease, removal of protective skin, increased water losses, and wilt and decay.

Fresh-Cut Fruits and Vegetables for the Processing Industry

Flavor encompasses taste and scent traits, with a very wide variety of combinations of sweetness, sourness, bitterness, and astringency, as well as the distinctive smells of each product and the absence of unwanted off-flavors and off-odors. Kader emphasises the relevance of nutritious and better-flavored fruits and vegetables in cultivar selection as a significant component in increasing sales and consumption.The nutrient content and biochemical makeup of the products vary because they may come from various regions of the plant. Roots and tubers have a high starch content; stems include fibres and skeleton-type tissues with a high lignin and cellulose content; and fruits have sugars, organic acids, mineral salts, pectic compounds, and enzymes. Quality parameters include soluble solids content, total or titratable acidity, pH, water content, density, and the ratio of soluble solids content to acidity. Fruits and vegetables are high in vitamins A and C, minerals, carbohydrates, dietary fibre, proteins, and antioxidant compounds such as carotenoids, flavonoids, and other phenolic compounds; however, their composition and concentration vary between cultivars and are influenced by pre- and postharvest practises.Fresh-cut produce safety regulations include good agricultural practises (GAP) and good processing procedures (GMF), the absence of plagues, mycotoxins, pesticide residues, and any other chemical or physical contamination that might endanger consumer health.

Lastly, because no changes are made to the items in the intact fruit market, the required quality features of fruits and vegetables for the fresh-cut business may differ from those for the intact fruit market. Processors require intact fruits and vegetables that can withstand processing and retain fresh-cut product quality attributes for as long as possible, with high production yields, very good and consistent quality, free of defects, and at the appropriate maturation stage; thus, the use of grocery store surplus or low quality and unmarketable products for processing should be avoided. The proper intact fruits and vegetables used as raw matter must enable the creation of high-quality fresh-cut goods with uniform and consistent quality, appropriate postcutting shelf-life, and consumer pleasure.

Fresh Fruits and Vegetables' Dynamic Behavior

Fruits and vegetables are made up of living tissues and must overcome two key challenges: harvesting and processing. When they are harvested, the mother plant's water and food supply is cut off, and tissues are harmed at the incision area. After the items are sliced and the product skin is removed, there is a rise in respiration and other metabolic processes that continue all the way up to the consumer table.Changes are always occurring in such a dynamic system, even if they are not visible for the first few hours or days following harvesting or cutting. Although many more physical, physiological, and biochemical changes are occurring at different speeds and are impacted by internal and external variables, appearance and texture changes are the first to be seen.

New Developments in the Processing of Fresh-Cut Fruits and Vegetables

The most significant intrinsic changes in fruits and vegetables are directly connected to external variables such as temperature, relative humidity, handling, microbiological, and other stressors that occur during pre- and postharvest activities.

Rate of Respiration

Internal factors such as product type and maturity stage influence respiration rate, as do external factors such as temperature, ethylene concentration, stress caused during harvest, postharvest, and processing operations, pathogens, and physical injuries. The greater the rate of respiration, the shorter the shelf life of intact and fresh-cut items. Respiration rate is a strong measure of continuing activities inside a product and how quickly they occur; goods collected during active growth (vegetables and immature fruits) often have high rates, whereas mature fruits and storage organs have relatively low rates.

Ethylene Manufacturing

Ethylene is involved in the growth, development, maturity, healing, and senescence of fresh food. Its manufacturing rate ranges from 0 50 100 150 200 250 300 350 0 1 5 1 0 5 20

1. Rate of respiration (mg CO_2/kg/h)
2. Temperature of storage (°C)
3. Asparagus Broccoli Carambola Pineapple Raspberry

Fresh-Cut Fruits and Vegetables for the Processing Industry It varies by product; it rises with temperature, disease incidence, mechanical damage, water stress, and harvest maturity stage; and it can be somewhat regulated by low temperature storage, reduced oxygen composition, or high carbon dioxide levels around the commodity. Because very low amounts of ethylene can harm sensitive items they must be handled separately from those that create it.

CHAPTER 11

WATER WASTE

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When the surrounding atmosphere has a low relative humidity, the water content of fruits and vegetables is quite high and can readily be lost through the skin lenticels, stomata, cuticule, and other structures. The skin of fruits and vegetables acts as a natural barrier that helps to control water loss, but its effectiveness is dependent on product morphology, surface characteristics, size, product surface area to weight and volume ratio, maturity stage, physical injuries, and environmental temperature, relative humidity, and air movement around the product. Certain items, such as lettuce and other green vegetables, wilt and shrivel and generally degrade quickly; others, such as apples and pears, are more resistant to water loss. Water loss increases for other products with rough, uneven, or extended surface area or with high stomata or lenticels density, such as rambutan, which has hair-like structures that favour water loss and desiccation, with external darkening occurring in a few days at 25oC and 60% relative humidity (Yingsanga et al. 2006), with weight losses ranging from 7% to 11% during the first storage day.

Fresh-cut items, on the other hand, might lose water much faster than whole products due to their higher surface area to volume ratio, since skin removal and damaged tissues caused by cutting processes encourage cellular content loss. Sharp knives and adequate packing materials are essential for such items to avoid water migration.Internal and External Color Color is one of the key quality aspects of fresh commodities that customers and the fresh-cut industry use as a selection criterion, as well as an indicator of the overall quality and maturation stage of the product. Preharvest variables such as plant nutrition, seasonality, climatic conditions, production lot, temperature, relative humidity, storage period, and postharvest handling conditions can all impact colour. Color changes can occur as a result of pigment component breakdown or production, such as chlorophylls (green), anthocyanins (red, blue, and purple), and carotenoids and flavonoids (yellow and orange) (Maestrelli and Chourot 2002; Kader and Barrett 2005). They can form naturally as a result of ripening, but they can also be induced by mechanical pressures on the cell wall, membranes, and tissues during produce handling and fresh-cut processing. Once enzymes and their substrates come into touch, such damage promotes fluid leakage, tissue weakening, and enzymatic browning processes (Singh and Cadwaller 2004). PPO (polyphenol oxidase) and POD (peroxidase) enzyme activity is also linked to colour variations in fruits and vegetables. PPO activity causes enzymatic browning in mangoes, avocados, peaches, apples, pears, bananas, olives, potatoes, mushrooms, lettuce, grapes, and other fruits and vegetables.

External variables such as high temperature, low relative humidity, physical injury, and other stress situations can hasten colour changes.

Odriozola-Serrano et al. (2009) discovered that when temperature and storage duration increased, the degradation of anthocyanins responsible for the attractive brilliant red colour of strawberries increased dramatically.

Color standards for fresh intact products differ from those for fresh-cut processing. External colour is one of the most essential quality criteria for the whole produce market, while both external and interior colours are vital for the industry. In general, colour should be bright and even, while retaining the fresh product's natural look. New cultivars with superior processing capabilities but significant colour variances must be handled with caution, since they may be rejected by consumers.

Texture

Texture properties change during pre- and postharvest handling because of maturation stage, plant nutrition, water stress, storage temperature and relative humidity, harsh handling, and ripening processes. Some of the changes that occur during product handling include softening, loss of turgidity, and increased elasticity or toughness, which may impair the product's value and usability for the fresh-cut sector. Modifications can occur as a result of water losses, as previously noted, or as a result of the activity of various enzymes or pathological breakdown in conjunction with handling circumstances. Enzymes such as -galactosidase, polygalacturonase, pectin methyl esterase, cellulose, phenilalanineammonia lyase, peroxidase, and cellulase participate in cell-wall modification; pectin compound degradation in tomatoes, melons, avocados, and peaches; pectin solubilization in strawberries; ripening initiation processes; tissue weakening and.

Physical damage to fresh fruits and vegetables should be avoided during harvest, transportation, and postharvest and processing processes since it reduces quality characteristics and shelf life. Symptoms may appear immediately, during processing, or after many days or weeks of storage; they are commonly described as tissue darkening, loss of firmness, bruising, fractures, cuts, and perforations, which result in quicker degradation reactions than intact goods. Damaged tissues promote microbial spoilage and other undesirable reactions by increasing respiration rates, water loss, and other metabolic reactions; allowing better contact between enzymes and their substrates; and promoting microbial spoilage and other undesirable reactions (Singh and Anderson 2004).

Fruits were rated as extremely fragile, delicate, resistant, or very resistant to handling by Maestrelli and Chourot (2002). They discovered that cultivar, maturation stage, and handling procedures impacted the responsiveness of peaches, pears, prunes, and apricots to mechanical injury. Damages are caused by impact, compression, penetration, vibration, and shear forces acting on the product; thus, they can be controlled by protecting and immobilising the product, which can be accomplished by careful handling, reducing unnecessary movements, drop heights, and any cut edges or rough surfaces that could threaten product integrity.

The responsiveness of apple and peach cultivars to processing varies, but fruit susceptibility can also be impacted by preharvest techniques, climatic conditions, maturation stage, and other factors that affect phenolic compound levels and enzyme activity.The impact of bruising on susceptibility is greater for sweet cherries handled at temperatures below 10oC compared to temperatures up to 20oC. Temperature has little effect on mechanical damages caused by vibration (Crisosto et al. 1993). Chilling and freezing injuries, on the other hand, contribute to tissue softening, water-soaked areas, ripening issues, surface and flesh discoloration, off-flavors and off-odors production, and increased susceptibility to microbial spoilage and.

Compositional Variations

The internal content of fruits and vegetables changes during growth and development, as well as after harvest. Modifications may be beneficial or undesirable, depending on the product and how and when it will be treated. Soluble solids concentration and acidity are two significant criteria for fruits that are usually associated with maturation stage, flavour, and customer preferences, and are utilised as quality factors for product selection for processing. Nonclimacteric fruits (pineapple, citrus fruits) undergo little modifications after harvest, but climacteric fruits undergo significant changes as they mature.

The loss of aroma components, as well as the formation of off-flavors and off-odors, have a direct impact on the flavour of fruits and vegetables. They have been linked to the maturity stage, adverse storage circumstances, or the enzymatic activity of peroxidases and lypoxygenases in chile peppers, broccoli, asparagus, carrots, and green beans.During handling and processing, antioxidants and other nutritional properties might be lost. Ascorbic acid is very sensitive to high temperatures, light, low humidity conditions, physical damages, and chilling traumas, according to Kader and Barret.

Development and expansion

After harvest, some fresh food continues to grow and develop. Rooting can occur in root crops and onions, seed germination in tomatoes and peppers, and asparagus elongation (Kader 2002a). To reduce these undesired changes, proper harvesting index selection, handling and storage conditions, and particular treatments are required. The majority of these changes are unfavourable for freshcut processing because metabolic activity rises and product appearance rapidly deteriorates.

Processing of Fresh-Cut Fruits and Vegetables Advances

Microbiological Spoilage

Fruits and vegetables are not only important providers of nutrition and water for people, but also for microbes, which may thrive in a variety of environments. Microorganisms can enter the fruits at many times of production, such as in the early stages of development or during postharvest handling and processing. Certain germs can swiftly degrade the appearance and other qualitative aspects of fruits and vegetables but do not pose a risk to consumers (phytopathogens), whereas others can be hazardous to consumer health (food safety related microorganisms). They are classified into two groups:

Fruit and vegetable microorganisms, which include moulds, yeast, bacteria, and viruses that impair product quality but do not pose a health concern to consumers.

Hazardous microorganisms: They can cause disease and even death in customers, yet they have no effect on the product's appearance or other quality qualities. While there are no signs of degradation in the goods, caution must be exercised to avoid product contamination. To avoid product contamination, sanitation initiatives in the fields and processing areas, as well as excellent sanitary procedures by operators, are required.

Technological Instruments for Preserving Fresh Produce for Processing

Quality is crucial in processed foods, but it is especially critical in fresh-cut fruits and vegetables, which must maintain the quality features of the intact product following cutting pressures without being subjected to any substantial temperature-stabilizing treatment. Hodges and Toivonen (2008) emphasised the significance of understanding that all methods applied to a fruit or vegetable create stress-induced alterations in tissue physiology and metabolism. They also emphasised the need of understanding how these changes occur in order to develop effective techniques for preserving product quality and extending shelf life.

As raw materials, the fresh-cut processing business requires high-quality fruits and vegetables. They must have a pleasing look, texture, taste, flavour, and nutritional value, as well as be safe for consumption. They must be free of mechanical injuries, rot, insects, and other problems, and they must withstand process operations as well as further handling and storage methods.Furthermore, to ensure adequate quality produce supply and prevent product losses, effective technological instruments must be implemented in each segment of the chain, from the producing fields to the processing sector.The success of a fresh-cut product is dependent on meeting the needs and expectations of the target consumer, using the proper fruits and vegetables at their optimum maturity stage for processing, using the right operation techniques and packages, and employing effective sales tactics.Preharvest, harvest, and postharvest management strategies for better intact fruits and vegetables for processing will be described later in this chapter.

Fruits and Vegetables for the Fresh-Cut Processing Industry

Assessment and Selection of Cultivars

For any sort of crop, there may be a few or many cultivars on the market, each with its own set of advantages and disadvantages when it comes to processing. Many fruits and vegetables have significant variation in respiration rates, colour, texture, bruising susceptibility, size, shape, appearance, nutritional value, sensory, and other characteristics, according to studies comparing cultivars.Cultivar selection for the fresh-cut industry looks for intact fresh fruits and vegetables that can meet the desired quality attributes for their fresh-cut product, withstand transportation and handling before processing, tolerate minor quality changes during processing, and have a long after-cutting shelf life. Because the characteristics and quality of intact fresh fruits and vegetables are constantly changing and influenced by environmental conditions, production technology during preharvest and postharvest handling, fresh-cut processing and packaging, and distribution to the final market, these four elements are interrelated.

Where feasible, industry need consistent high-quality agricultural goods throughout the year in order to manufacture uniform fresh-cut items without interruption. To prevent consumer concerns, cultivar selection must be followed by suitable preharvest techniques, harvesting indications, postharvest handling operations and storage before processing, and food safety protocols.

Fruits and vegetables with the greatest and most consistent quality features are ideal for fresh-cut processing: High field production and processing yields; year-round availability; free of physical, physiological, or pathological disorders; easy to handle; highly resistant to handling and all processing operations and stabilising treatments; little susceptible to external conditions; with a prolonged shelf life after processing to maintain quality attributes all the way to the consumer and safe consumption.

It should also satisfy customer preferences and market requirements.Certain specifications are required for individual items. Processors must clearly define the characteristics of their final products in order to evaluate cultivar response to handling, processing, and after-cutting handling and to identify limiting factors such as juice leaking, discoloration, browning, wilting, microbial spoilage, and others that may limit fresh-cut product shelf life. The impact of harvesting indications, handling, and processing procedures on end product quality should also be assessed.

Gorny et al. (1999) discovered that the main elements influencing fresh-cut peach and nectarine slice quality were regulated by product reaction to cutting, which was better when the flesh firmness was between 13 and 27 N and the fruits were kept at 0oC and 90% to 95% relative humidity. The same authors (2000) investigated the appropriateness of Anjou, Bartlett, Bosc, and Red Anjou pear cultivars for fresh-cut slices production in another study and discovered substantial variations in respiration and ethylene production rates, flesh hardness, colour, and susceptibility.

196 Fresh-Cut Fruits and Vegetables Processing Leads to cut-surface browning, which was extremely pronounced for Anjou and Red Anjou cultivars.Milani and Hamedi (2005) investigated the browning rate of five apple cultivars and discovered disparities; the Red Delicious cultivar had the greatest browning rate, followed by Golden Delicious with a medium rate, while Granny Smith and Golden Smoty had a low browning rate. Toivonen et al. (2006) investigated sweet cherry cultivars for fresh-cut processing and reported that the majority of them were appropriate for fresh-cut processing because they maintained firmness despite variances in postcutting bleed, weight loss, and decay throughout storage. These are some tips for selecting fruits and vegetables cultivars for fresh-cut processed products:

1. Establish acceptable fresh-cut product quality characteristics and tolerance ranges (colour, shape, size, flavour, soluble solids content, acidity, texture, juiciness, nutritional content, etc).
2. Select cultivars with consistent and dependable quality that can fulfil product idea requirements.

3. Examine fresh-cut product quality and shelf life in terms of visual and eating quality, as well as microbiological safety; examine deteriorative changes that impair marketability, such as browning, water-soaked tissues, translucency, softening, composition changes, microbial growth, decay, or others.
4. Assess cultivar processing aptitude by examining product reaction to handling and processing, as well as sensitivity to deteriorative changes before, during, and after cutting.
5. Identify the harvest maturity stage and, if necessary, ripening treatments.
6. Assess processing yields (usable product per kilogramme of intact fruit or vegetable, processing time per kilogramme of prepared fresh-cut product, etc.).
7. In circumstances when a cultivar is selected despite some restrictions, consider alternate treatments to reduce undesirable browning, softening, or other changes on the fresh-cut product.
8. Calculate the finished product's projected postcutting shelf life at handling temperatures.
9. Research product compatibility for mixed fresh-cut fruits and vegetables.
10. During the year, look for potential suppliers, production sites, agricultural techniques, traceability, product quality, and availability.
11. Evaluate product response to automation where possible and convenient to minimise processing time, reduce contamination concerns, and boost yields.

Preharvest Techniques to Enhance Produce Quality

Product quality is affected by genetic material, sowing, growth circumstances, light intensity throughout the production period, pruning, product thinning, harvest maturity, nutrients and water availability, soil quality, fertilisation, weed control, and insect management.Climate Conditions for Fruits and Vegetables for the Fresh-Cut Processing Industry 197 (Hodges and Toivonen 2008; Kader 2008). As a result, rigorous production plans must be executed with the goal of strengthening the chosen feature of a certain crop and, as a result, the ultimate quality and shelf life of freshcut items. The impacts of some preharvest activities are disclosed ahead of time.

Crop rotation is advised for its favourable influence on product quality, as opposed to the decay inoculum of soilborne fungus, bacteria, and nematodes that would develop up in producing fields from repeated cropping of the same produce (Crisosto and Mitchell 2002). According to the same authors, fruitlet thinning, location within the tree, pruning, and other cultural activities influence fruit size and productivity.Irrigation is critical for all crops since plant tissues require water to survive. Insufficient water supply may stress the product and make it more susceptible to sunburns, change maturation processes in pears, and cause a leathery texture in peaches, but moderate water stress can lower fruit size while increasing soluble solids content, acidity, and ascorbic acid concentration. Gelly et al. also observed that deficit watering on peaches (Prunus pérsica L.) enhanced soluble solids content and aided in the preservation of fruit colour. Excess water stress, on the other hand, may produce cracking failures in cherries, apricots, tomatoes, and other products; lower firmness and soluble solids content; and increase susceptibility to mechanical damage owing to an excess of turgidity. Plants can also be stressed by the presence of salt in irrigation water. Kim et al. investigated the effects of water salinity on romaine lettuce stress. When compared to a control treatment without salt, sodium chloride concentrations over 100 mM resulted in a 1.5- to 3-fold loss in lettuce height and weight. Color losses increased as sodium chloride concentrations rose.Irrigation with salt water also affects the concentration of carotenoids and phenolic chemicals. Fonseca (2006) discovered that stopping irrigation 4 days before harvesting instead of 16 days before harvesting enhanced product weight and diameter, but increased aerobic bacteria numbers, resulting in quicker deterioration of product quality. Kim et al. (2008a) discovered a 30% increase in lycopene and vitamin C content when whole tomatoes were irrigated with salt water, but not in phenolic compounds. The kind of substrate also has an impact on quality qualities.

Fertilization influences both harvest quality and postharvest shelf life of fruits and vegetables. Nutritional balance is important because deficiencies or excesses can promote physiological diseases and degrade product quality and shelf life. High nitrogen fertilisation is used to improve product size, but it can also limit volatile component synthesis and encourage changes in product flavour; other elements, such as high potassium, can lessen colour disorders while high magnesium can increase them (Crisosto and Mitchell 2002). Plant nutrition variances can influence product size, stiffness, and sensitivity to weight loss. Calcium has been linked to a decrease in respiration rate and ethylene production, an increase in firmness, and a slowing of ripening and deteriorative responses (Kader 2002b).

New Developments in the Processing of Fresh-Cut Fruits and Vegetables

Hodges and Toivonen (2008) compared the quality attributes of tomato slices grown in hairy vetch and black polyethylene mulch and discovered that those grown in hairy vetch mulch were firmer, had fewer water-soaked areas, and had a lower increase in electrical conductivity, indicating stresses associated with chilling injuries and membrane damage, respectively.Calcium chloride sprays have been used successfully on Anjou pears to minimise browning core, cork spots, superficial scald diseases, and external and internal rots, with an overall increase in fruit appearance and fruit juiciness and colour.

The intrinsic qualitative features of the items, as well as their sensitivity to handling and processing, are affected by climatic circumstances (temperature, rain, wind, and light).Climate conditions can be somewhat regulated in growing regions through the use of shading, drainage, and wind breakers; they can also be accurately managed in greenhouse plantations. Jolliffe (1996) discovered an important reduction in skin chlorophyll content and shelf life for low light intensity on greenhouse-grown English cucumbers; such a reduction can be avoided by using supplemental light during growing, which increases product yields, external and internal quality of many vegetables, including cucumber dry matter content and skin chlorophyll content, tomato ascorbic acid and sugar content, and lettuce head firmness.

In Europe and South America, there is a movement towards shifting from traditional growing to protected areas cultivation for greater control throughout produce production.A variety of simple and complex technologies are used to control temperature, relative humidity, and irrigation control, and more recently, floating trays with a nutrient solution supply were incorporated, and small leaves grow with a significant reduction in nitrate accumulation and microbial load, both of which are desirable for fresh-cut processing.

Indicators of Harvest and Maturity

Product composition, postharvest tolerance to handling and processing operations, and postcutting life are all affected by the stage of maturity at harvest.Fruit and vegetable maturity at harvest determines their susceptibility to processing and degradation responses. Toivonen (2008) investigated the influence of harvest ripeness on the cut-edge browning susceptibility of antibrowning treated apple slices. He discovered that even after commercial antibrowning treatments, the cutting surface of slices from Granny Smith apples harvested before optimal harvest ripeness is more prone to browning. Fruit maturity of pear slices at cutting influenced shelf life; it ranged from 2 days at 0°C for ripe fruit to more than 8 days for partially ripe and mature-green pears; and it also influenced surface darkening at 0°C, which was greatly decreased for partially ripe and mature-green fruit. The eating quality of mature-green pear slices, on the other hand, lacked juiciness and fragrance.

Harvesting criteria differ depending on the product: how it will be consumed or processed, distance to markets, anticipated storage period and temperature, and industry.Fruits & Vegetables for the Fresh-Cut Processing Industry 199 specifications, customer preferences, and a variety of other factors. Some produce, such as mangoes, papayas, and plantains, have different uses for green-mature and fully ripe products; vegetables are obtained from different parts of the plant, such as leaves, flowers, sprouts, roots, and tubers that reach their best quality attributes at various stages of growth and development of the plant, so there is a wide range of harvesting possibilities, depending on the final destination.Maturation or harvesting indices have been established to indicate the optimal harvesting time for improved quality and shelf life. Harvest indices must be straightforward, easy to comprehend and implement, dependable, the result of objective measurement, and, if feasible, nondestructive.

Methods for Preserving Fresh Food for Processing Using Technology

Quality is an important factor in processed foods, but it is especially important for fresh-cut fruits and vegetables, which must keep the quality characteristics of the intact product during cutting forces without being subjected to any major temperature-stabilizing treatment. Hodges and Toivonen emphasised the need of comprehending that all procedures used on a fruit or vegetable cause stress-induced changes in tissue physiology and metabolism. They also stressed the need of knowing how these changes occur in order to develop efficient methods for protecting product quality and increasing shelf life.

As raw materials, the fresh-cut processing business requires high-quality fruits and vegetables. They must have an appealing appearance, texture, taste, flavour, and nutritional content, as well as be safe to eat. Mechanical damage, rot, insects, and other issues must be avoided, and they must endure production activities as well as subsequent handling and storage procedures.Additionally, to ensure correct quality produce supply and minimise product losses, effective technological instruments must be used at each segment of the chain, from the production fields to the processing sector.

A fresh-cut product's success is contingent on satisfying the demands and expectations of the target consumer, utilising the correct fruits and vegetables at their optimal maturity stage for processing, using the right operation techniques and packaging, and applying successful sales strategies.This chapter will go deeper into techniques for better intact fruits and vegetables for processing, such as preharvest, harvest, and postharvest management.

Assessment and Selection of Cultivars

For every crop, there may be a few or many cultivars on the market, each with its own set of processing benefits and drawbacks. When comparing cultivars, many fruits and vegetables demonstrate substantial diversity in respiration rates, colour, texture, bruise susceptibility, size, shape, appearance, nutritional value, sensory, and other properties.

Cultivar selection for the fresh-cut industry seeks intact fresh fruits and vegetables that can meet the predetermined quality attributes for their fresh-cut product, withstand transportation and handling prior to processing, tolerate minor quality changes during processing, and have a long after-cutting shelf life. These four elements are interconnected because the characteristics and quality of intact fresh fruits and vegetables are constantly changing and influenced by environmental conditions, production technology during preharvest and postharvest handling, fresh-cut processing and packaging, and distribution to the final market.

Industry need constant, high-quality agricultural supplies throughout the year, if possible, in order to produce uniform fresh-cut items without interruption. To avoid consumer hazards, cultivar selection must be followed by suitable preharvest activities, harvesting indications, postharvest handling operations and storage before processing, and food safety measures.

The best fresh-cut fruits and vegetables have the highest and most consistent quality attributes: High field production and processing yields; year-round availability; free of physical, physiological, or pathological disorders; easy to handle; highly resistant to handling and all processing operations and stabilising treatments; little susceptible to external conditions; and with a prolonged shelf life after processing to maintain quality attributes all the way to the consumer and safe consumption. It should also meet client likes and preferences as well as market requirements.Each goods must meet certain standards. Processors must clearly define their final products' attributes in order to evaluate cultivar response to handling, processing, and after-cutting handling and identify limiting factors such as juice leaking, discoloration, browning, wilting, microbial spoilage, and others that may limit fresh-cut product shelf life. It is also necessary to analyse the impact of harvesting indications, handling, and processing techniques on final product quality.

Gorny et al. observed that the primary factors impacting fresh-cut peach and nectarine slice quality were product reactivity to cutting, which was better when the flesh firmness was between 13 and 27 N and the fruits were stored at 0oC and 90% to 95% relative humidity. The same authors (2000) investigated the suitability of Anjou, Bartlett, Bosc, and Red Anjou pear cultivars for fresh-cut slices production and identified significant differences in respiration and ethylene production rates, flesh hardness, colour, and sensitivity.

196 Enhancements to Fresh Fruits and Vegetables Processing resulted in cut-surface browning, which was especially severe in Anjou and Red Anjou cultivars.Milani and Hamedi (2005) studied the browning rate of five apple cultivars and identified disparities; the Red Delicious cultivar had the greatest browning rate, followed by Golden Delicious at a medium pace, and Granny Smith and Golden Smoty at a moderate rate. Toivonen et al. (2006) evaluated sweet cherry cultivars for fresh-cut processing and found that the majority of them were adequate for fresh-cut processing due to their ability to maintain firmness despite variations in postcutting bleed, weight loss, and degradation throughout storage.

These are some options for cultivars of fruits and vegetables for fresh-cut processed products:

1. Determine the appropriate fresh-cut product quality features and tolerance limits (colour, shape, size, flavour, soluble solids content, acidity, texture, juiciness, nutritional content, etc).
2. Identify cultivars with consistent and predictable quality that can meet the product idea.
3. Consider deteriorative changes that reduce marketability, such as browning, water-soaked tissues, translucency, softening, composition changes, microbial growth, decay, or others, when looking for limiting factors to fresh-cut product quality and shelf life based on visual and eating quality as well as microbial safety.
4. Evaluate cultivar processing aptitude by observing product reactivity to handling and processing, as well as sensitivity to deteriorative changes prior to, during, and after cutting.
5. Determine harvest maturity stage and ripening operations as needed.

Investigate processing yields (usable product per kilogramme of intact fruit or vegetable, processing time per kilogramme of prepared fresh-cut product, etc.).Consider other treatments to eliminate undesirable browning, softness, or other changes on the fresh-cut product when a cultivar is preferred despite certain constraints.Determine the final product's estimated postcutting shelf life at handling temperatures. Look at cross-product compatibility for mixed fresh-cut fruits and vegetables.During the year, look for possible suppliers, production sites, farming practises, traceability, product quality, and availability.Analyze product reaction to automation whenever possible and practical to minimise processing time, eliminate contamination issues, and boost yields.

CHAPTER 12

PREARREST METHODS TO IMPROVE PRODUCE QUALITY

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Product quality is affected by genetic material, sowing, growth conditions, light intensity throughout the production period, pruning, product thinning, harvest maturity, nutrients and water availability, soil quality, fertilisation, weed control, and pest management.Climate-controlled fruits and vegetables for the fresh-cut processing sector 197 (Hodges and Toivonen 2008; Kader 2008). As a result, rigorous production tactics must be used in order to increase a certain crop's selected characteristic and, as a result, the final quality and shelf life of freshcut goods. Many preharvest practises are detailed ahead of time.

Crop rotation is recommended because it improves product quality in comparison to the degrading inoculum of soilborne fungus, bacteria, and nematodes that would grow in producing fields from repeated cropping of the same produce Fruitlet thinning, position within the tree, pruning, and other cultural practises, according to the same authors, all have an effect on fruit size and yield.Irrigation is essential for all crops since plant tissues need water to survive. Low water supply may stress the product and increase its susceptibility to sunburn, but moderate water stress may reduce fruit size while increasing soluble solids content, acidity, and ascorbic acid concentration (Kader 2002a). Gelly et al. (2003) discovered that deficient watering on peaches (Prunus pérsica L.) increased soluble solids content and aided in the preservation of fruit colour. Excessive water stress, on the other hand, may result in cracking failures in cherries, apricots, tomatoes, and other products; decreased firmness and soluble solids content; and increased susceptibility to mechanical damage owing to turgidity. The presence of salt in irrigation water can also stress plants. Kim et al. investigated the effects of water salinity on the stress of romaine lettuce (Lactuca sativa cultivar Clemente).

As compared to the control treatment without salt, sodium chloride concentrations over 100 mM resulted in a 1.5- to 3-fold reduction in lettuce height and weight. As sodium chloride concentrations increased, colour loss occurred.The content of carotenoids and phenolic compounds is also affected by irrigation with salt water. Fonseca (2006) showed that when irrigation was stopped four days before harvesting rather than sixteen, the product weight and diameter increased, but aerobic bacteria counts increased, resulting in faster deterioration of the product's quality. Kim et al. (2008a) discovered a 30% increase in lycopene and vitamin C content when whole tomatoes were irrigated with salt water, but not in phenolic compounds. The substrate has an impact on quality aspects as well.

Fruit and vegetable fertilisation affects both harvest quality and postharvest shelf life. Nutrients must be balanced since deficiencies or excesses can produce physiological disorders as well as decrease product quality and shelf life. High nitrogen fertilisation is used to enhance product growth, but it can limit volatile component synthesis and stimulate flavour alterations; other elements, such as high potassium, can reduce colour disorders while high magnesium can increase them. Variables in plant nutrition can affect product size, hardness, and weight loss susceptibility. Calcium has been associated to a reduction in respiration rate and ethylene production, as well as an increase in firmness and a pause in ripening and deteriorative reactions (Kader 2002b).

Hodges and Toivonen (2008) compared the quality attributes of tomato slices grown in hairy vetch vs. black polyethylene mulch and discovered that those grown in hairy vetch vs. black polyethylene mulch were firmer, had fewer water-soaked areas, and had a lower increase in electrical conductivity, stress associated with chilling injuries, and membrane damage, respectively.Calcium chloride sprays have been used successfully on Anjou pears to reduce browning core, cork spots, superficial scalds illnesses, and external and internal rots, resulting in an overall improvement in fruit appearance, juiciness, and colour.

The fundamental qualitative features of the products, as well as their susceptibility to handling and processing, are influenced by climatic conditions (temperature, rain, wind, and light).Climate conditions can be moderated in growing regions by utilising shades, drainage, and wind breakers; they can also be precisely managed in greenhouse plantations. Jolliffe (1996) discovered a significant reduction in skin chlorophyll content and shelf life for low light intensity on greenhouse-grown English cucumbers; this reduction can be avoided by using supplemental light during growing, which increases product yields, external and internal quality of many vegetables, including cucumber dry matter content and skin chlorophyll content, tomato ascorbic acid and sugar content, and lettuce head firmness.In Europe and South America, there is a trend towards transitioning from traditional farming to protected area farming in order to have more control over food output.A variety of simple and complex technologies are used to control temperature, relative humidity, and irrigation control, and more recently, floating trays with a nutrient solution supply were incorporated, and small leaves grow with a significant reduction in nitrate accumulation and microbial load, both of which are important for fresh-cut processing.

Indicators of Harvest and Maturity

It influences product composition, postharvest tolerance to handling and processing operations, and postcutting life.Fruit and vegetable maturity at harvest impacts how they react to processing and deterioration. Toivonen (2008) evaluated the effect of harvest ripeness on the cut-edge browning susceptibility of antibrowning treated apple slices. He observed that even after commercial antibrowning treatments, the cutting surface of slices of Granny Smith apples picked before ideal harvest maturity is more vulnerable to browning. Fruit maturity of pear slices at cutting influenced shelf life, which ranged from 2 days at 0°C for ripe fruit to more than 8 days for partially ripe and mature-green fruit; and it also affected surface darkening at 0°C, which was greatly decreased for partially ripe and mature-green fruit. Regrettably, the juiciness and aroma of mature-green pear slices were lacking. Harvesting criteria differ depending on the commodity, including how it will be eaten or processed, distance to markets, estimated storage length and temperature, and industry.

Client preferences, and a range of other considerations. Mangoes, papayas, and plantains, for example, have different uses for green-mature and fully ripe products; vegetables are obtained from various parts of the plant, such as leaves, flowers, sprouts, roots, and tubers, which reach their best quality attributes at various stages of growth and development of the plant, so there is a wide range of harvesting possibilities, depending on the final destination.Harvesting indices have been developed to suggest the ideal time to harvest for increased quality and shelf life. Harvest indices must be straightforward, easy to comprehend and implement, dependable, the result of objective measurement, and, if feasible, nondestructive.Individual phenolic content, antioxidant capacity, carotenoids, ascorbic acid, and capsaicin concentration differed between sweet pepper genotypes and maturation stage. According to Kader, nonfruit veggies have higher quality flavour when picked immature, but fruit vegetables and fruits have better quality taste when harvested fully ripe.

Fruit harvesting requirements also include form, size, and aesthetic standards, but flavour and scent play a significant influence. They have a significant impact on product quality since the synthesis of aroma-related volatile and nonvolatile compounds rises as the product grows and ripens (Kader 2008). Because additional aspects, such as the type of product, resistance to handling and processing, time necessary to reach the ultimate market, production pricing, how it is processed or eaten, and others, must be addressed, optimal amounts of such compounds may not always meet the harvesting requirements. Harvest date for apples is determined by a number of factors, including days from full bloom as a rough estimate of fruit maturity, background colour, ease of separation of the fruit from the spur, soluble solids content, starch conversion into sugars, flesh firmness, and internal ethylene concentration.The right selection of harvesting indicators is critical for climacteric fruits, since if fruits are plucked prior to physiological development, in an early phase of preclimateric stage, fruit quality characteristics will not achieve acceptable levels. Robles et al. investigated changes in Ataulfo mangoes as they matured and discovered a rise in total soluble solids and ethylene production rate, as well as a steady decrease in respiration rate, acidity, and hardness. When processed before the full maturity stage, Maradol papaya, Keitt mangoes, and Red Spanish pineapple produce superior outcomes for fresh-cut processing, which is explained by decreased hardness and colour variations during postcutting storage.

In conclusion, harvest maturity influences qualitative characteristics and after-cutting shelf life of intact and fresh-cut produce, and harvesting indices should be changed to account for product reaction to handling and processing. Under- or overmature produce results in inadequate quality characteristics and low yields, whereas overmature goods reduce fresh-cut product postcutting shelf life and increase susceptibility to degradation, mechanical damage, microbiological spoilage, and other damages.Minimize Metabolic Activity by Using the Best Storage Temperatures Temperature is the most critical external component to regulate during postharvest handling and storage prior to processing since it governs the majority of the changes that take place inside an intact or fresh-cut fruit or vegetable. Because most processes slow down when the temperature decreases, quality qualities can endure for extended periods of time.

For undamaged and fresh-cut fruit and vegetables, the optimal storage temperature should always be chosen.Fresh-cut products should be stored at 5oC or below as a general rule, but the optimum temperature for intact products may be higher for chilling sensitive fruits and vegetables, and it must be considered for produce storage before processing. Some produce can withstand temperatures near freezing (0oC and below), while others require temperatures near 0oC. Fresh-Cut Fruits and Vegetables Advances Processing injury disorders, depending on the product, cannot be stored at temperatures below 7 to 13oC. Temperatures lower than those tolerated by the intact produce will result in uneven ripening, flavour, colour, and aroma losses, texture changes, and other undesirable changes.

For nonchilling-sensitive commodities, the rates of respiration and deterioration increase two to three times for every 10oC increase in the produce handling temperature range of 0 to 30oC. (Kader 2002a; Saltveit 2004a). Crisosto et al. (1993) discovered that sweet cherry respiration rates increased rapidly from nearly 10 mg CO2/kg/h at 0oC to 45 to 50 mg CO2/kg/h at 20oC, though response to temperature varied among cultivars, indicating differences in fruit sensitivity to temperature changes.High temperatures are also harmful, though some product tissues can tolerate them for short periods of time; they cause phytotoxic symptoms, which lead to accelerated deterioration (Saltveit 2004a). To reduce quality losses, avoid prolonged exposure to sunlight in the fields, transportation trucks, or during storage. Once the produce has been processed, the temperature must be kept at 5oC to minimise changes in the fresh-cut product's quality attributes as well as microbial spoilage.

Control of Relative Humidity and Water Loss

After temperature, relative humidity is the second most important factor in quality maintenance. Water loss reduces the shelf life and value of fruits and vegetables by causing appearance deterioration, tissue softening, wilting, shriveling, and weight loss. Such changes also have an impact on product suitability for the fresh market and the fresh-cut industry, because commodity resistance and yield deteriorate during processing and handling, making it more prudent to have a shorter shelf life for the product.Fresh produce is not a solid pack, but rather a porous material with its own internal atmosphere, which has a high relative humidity. Because of relative humidity differences between the internal and external atmospheres, they lose water through the skin or abscission cuts. As a result, in addition to optimum storage temperature, fresh produce should be stored in high relative humidity environments. However, storage requirements differ because water losses are also affected by skin and other product characteristics, making some products more vulnerable to losses than others. Dáz-Pérez et al. investigated water loss relationships with intrinsic bell pepper characteristics such as fruit size, maturity stage, cuticle thickness, and natural wax on the product surface, and found that water loss was greater through the calyx or stem scar than through the product skin, as previously reported for eggplants and tomatoes.

Although water loss cannot be completely eliminated, it can be reduced through careful handling and proper storage temperature and relative humidity conditions. Temperature should be as low as the product can tolerate without experiencing chilling injury symptoms, and relative humidity should be greater than 80% for most products, and up to 95% to 100% for products that are particularly sensitive to water loss, such as leafy vegetables and strawberries. Packaging materials, waxing of produce, and reduced exposure to air movement may also aid in reducing water losses.

Cold air is typically used for produce cooling and storage; it removes heat from the produce and transports it to the refrigeration system's evaporator. The faster the air passes through the produce, the faster it cools. However, once the product is cold, excess air movement favours water losses, so it should be kept as low as possible to allow proper ventilation without major losses. Adequate package sizes and ventilation, as well as proper product layout in storage rooms, can help to control excessive air exposure.

Light

Because solanine and chlorophyll are produced when potatoes are exposed to light, they green up during storage. Such changes are undesirable and can be avoided by storing in the dark. Green vegetables that are stored without light for an extended period of time may discolour. The light effect begins in the fields or greenhouses; light intensity also affects flavonoids, thiamine, riboflavin, carotenoids, ascorbic acid, and other compounds found in fruits and vegetables during growth, affecting their composition and nutritional quality.

The Composition of the Atmosphere

During respiration, cells and tissues require oxygen and produce carbon dioxide. Low oxygen and high carbon dioxide concentrations in the atmosphere surrounding the fruit or vegetable can be used to delay deterioration and extend shelf life.

Ethylene

Ethylene is a plant regulator that influences growth, development, ripening, senescence, and postharvest quality (Watkins 2006). Low levels of ethylene in the surrounding environment can cause climacteric fruits to ripen and some fruits and vegetables to undergo undesirable reactions such as colour loss and senescence. Sensitivity to ethylene varies by product, and changes can be desirable or undesirable, but as a general rule, very low concentrations of ethylene are required to affect product quality. Controlled ethylene application can be used for uniform maturation and degreening but should be avoided for long-term storage. As a general rule, ethylene producers must always be kept separate from ethylene-sensitive products.

Handling and Processing

Mechanical damage to fruits and vegetables is caused by impact, compression, shear, and puncture forces applied to the product during harvesting and handling all the way to the consumer or processing industry. Such damage hastens metabolic processes and promotes microbiological spoilage. Some of these damage symptoms can only be detected after several days of storage, during processing, or during subsequent storage, but they have a significant impact on product quality, stability, and shelf life. In order 204, stress caused by physical efforts during handling should be reduced. Advances in Fresh-Cut Fruits and Vegetables Processing to supply raw materials that can withstand additional stress processes during fresh-cut processing.

Varoquaux (2002) proposed that peeling and cutting damage product cells, increasing membrane permeability and, possibly, reducing phospholipid biosynthesis. These events cause the restoration of cellular microstructures and membrane integrity, the production of aldehydes with long carbonated chains, an increase in respiration rate, and the rapid consumption of cellular metabolites and subsequent deterioration. However, produce response to stress depends on the type of fruit or vegetable, its stage of development or maturity, and environmental conditions, and thus it can vary for a single product, such as kiwi, where ethylene production rise due to cutting stress can be very rapid or take several hours.

Field and Storage Packages

The primary function of packaging is to protect fresh fruits and vegetables from mechanical injuries, contamination, and other damages during postharvest handling. Packages should have smooth surfaces and edges, be resistant to staking, be the appropriate size and shape for the product, be easy to handle, allow proper ventilation for cooling, and be readily available. Some packages should have water loss barriers or other special requirements. Packages for fresh fruits and vegetables used for fresh-cut processing are only used to protect the product as it is transported from the fields to the processing plant, as well as for short-term storage prior to processing.

Conditioning and Storage before Processing

Fresh-cut product quality begins with fresh fruits and vegetables that have been properly handled during preharvest, harvest, and postharvest. The fresher the prime matter, the better the final product.Temporary storage between harvesting and processing also affects the quality and shelf life of fresh-cut products; in general, the longer the delay before processing, the shorter the shelf life. However, because fresh-cut products are very perishable, lasting between 1 and 2 weeks, temporary storage of intact fruits and vegetables will be convenient. Tropical or template fruits, roots, tubers, or other vegetables brought from distant markets could be processed at the final market, though some quality attributes may be compromised.In terms of cultivar selection, the effect of storage prior to processing should be investigated for specific intact fruits and vegetables and their fresh-cut products.

To preserve quality, products to be stored prior to processing should be conditioned before storage or transportation to the market where they will be prepared. Product selection (separation of culls), washing, classification based on quality criteria, stabilising treatments such as the application of growth regulators, antifungal treatments, curing, packaging, and cooling are all common preparation operations.Induced fruit ripening could be useful for obtaining uniform product characteristics prior to processing. It is usually done under controlled conditions of temperature, humidity, and air circulation. Ethylene generator devices produce excellent results with banana, tomato, avocado, plantain, and other fruits.

In contrast, 1-methylcyclopropene (1-MCP) has been widely used to reduce the action of ethylene in fruits and vegetables. Several authors have reported that colour changes, tissue softening, and other changes that occur during ripening are significantly delayed (Schouten and Kooten 2004). 1-MCP (1-methylcyclopropene) inhibits ethylene action and ripening reactions. It is applied at 20 to 25°C in low concentrations (2.5 nL/L to 1 μL/L) for 12 to 24 hours, but results depend on cultivar, development stage, time from harvest to treatment, and multiple applications. Effects vary among fruits and vegetables, including delay in respiration rate, ethylene production, volatile production, colour changes, chlorophyll degradation, membrane changes, softening, acidity and sugars variation, and development of disorders and diseases. It protects products from endogenous and exogenous sources of ethylene. Chlorophyll degradation and colour changes are prevented or delayed in oranges, broccoli, tomato, avocado, and other green vegetables, and volatile development is inhibited in several apple cultivars, apricots, melons, bananas, and other fruits. Product softening is also delayed in fruits such as avocado, custard apple, mango, papaya, apple, apricots, pears, mature plums, peaches, nectarines, and tomato. As product ripening and senescence processes are delayed or inhibited, the product shelf life is increased. McArtney et al. (2008) studied preharvest applications of 1-MCP in Golden Delicious apples, and they were able to reduce the rate of softening of the fruit during storage. Storage of intact fruits and vegetables should be carried out at their optimal temperature and relative humidity levels.

Treatments to Ensure Safety of Fresh-Cut Fruits and Vegetables

The highest priority of fresh-cut processors is the safety of their products. Freshcut products are considered “ready to eat” owing to the wash process used in their preparation. It is possible to reduce the numbers of pathogens on produce by washing produce in water, but it is not possible to eliminate human pathogens through any technology other than thorough cooking or irradiation. Thus it is essential to prevent the presence of pathogens with produce food safety programmes including Good Agricultural Practices (GAPs), Good Manufacturing Practices (GMPs), and Hazard Analysis Critical Control Point (HACCP) programmes.

Washing of Fresh-Cut Produce

The proper washing of fresh-cut produce immediately after cutting is one of the most important steps in fresh-cut processing (Gil and Selma, 2006).

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Fresh-Cut Fruits and Vegetables Advances Processing guidelines for the fresh-cut produce industry generally specify a washing or sanitising step to remove dirt, pesticide residues, and microorganisms responsible for quality loss and decay. The washing is based on conveying the product under water across an upward flow of air bubbles or pressurised water into the water tank, which might contain a sanitising agent. This step is also used to pre-cool cut produce and remove cell exudates that adhere to product cut surfaces supporting microbial growth or resulting in discoloration.

Washing with water alone removes only the free cellular contents that are released by cutting; it is ineffective in assuring fresh-cut produce safety.Pathogens can survive for relatively long times in water, or in plant residue entrapped in process line equipment or biofilms, and can subsequently contaminate clean product that passes through that water.The large operational costs of water use have resulted in the industry-wide common practice of reusing or recirculating washwater (Luo, 2007). This causes the efficacy of the washing to be affected by the presence of organic matter in the water and allows microorganisms to survive for relatively long times in water or attached to plant tissue. The effectiveness of the washing depends, therefore, on the quality of the washwater. The product should be washed and rinsed with processing water visually free of dust, dirt, and other debris and sanitised. The U.S. Food and Drug Administration (FDA) guide to minimise microbial food safety hazards of fresh-cut fruits and vegetables points out that adequate water quality is critical in a fresh-cut processing facility (FDA/CFSAN, 2008).

It is well known that fresh-cut processors usually rely on wash-water sanitizers to reduce initial bacterial populations in their fresh-cut products as a strategy to maintain their quality and extend their shelf life. There is a concern that reduction in surface populations reduces competition for space and nutrients and could promote the growth of potential pathogenic microorganisms. Some of the researchers evaluated the sanitizer efficacy by determining microbial reductions at day 0, but these differences disappear after storage. This fact has been supported by several authors who suggested that microbial populations of fresh-cut fruits and vegetables could increase most rapidly and even reach equal or highest numbers after treatment with antimicrobial solutions compared to water controls. Some authors asserted that microbiology will affect overall product quality.

However, it has been demonstrated that neither the level of total count nor the level of specific spoilage microorganisms per se can directly predict the sensory quality of a product. Many published studies support this view, as in many cases total bacterial numbers bear little or no relationship to product quality or shelf life. Furthermore, authors who initially correlated food quality and safety have demonstrated that given enough time, microorganisms can grow to high populations in packaged produce in the absence of obvious sensory defects Therefore, the goal of washing is not necessarily to remove as many microorganisms as possible from the produce. Rather, the challenge is to ensure that the microorganisms present do not Treatments to Ensure Safety of Fresh-Cut Fruits and Vegetables 213 create human health risk and that if harmful microorganisms should inadvertently be present, that environmental conditions prevent their growth. Therefore, the best method to eliminate pathogens from produce is to prevent contamination in the first place. It is more difficult to decontaminate produce than it is to avoid contamination. However, this is not always possible, and the need to wash and sanitise many types of produce remains of vital importance to prevent disease outbreaks.

Why Water Disinfection Is Needed

Washwater in tanks, recirculated water, or water that is reused in a spray-wash system can become contaminated with pathogens if contaminated product coming in from the field is washed in that water. Disinfection is the treatment of process water to inactivate or destroy pathogenic bacteria, fungi, viruses, and other microorganisms. Water is one of the key elements in maintaining the quality and safety of the fresh-cut products. The goal of disinfection is to prevent the transfer of microorganisms from process water to produce and from a contaminated produce to another produce over time. Even though washing can remove some of the surface microorganisms, it cannot remove all of them. Microorganisms adhere to the surface of produce and may be present in nooks and crannies where water and washwater disinfectants cannot penetrate. Commercial sanitizers can be very effective in eliminating free-floating or exposed microorganisms on produce surface. However, they are especially effective to disinfect, not to sanitise, produce. Clean, disinfected water is necessary to minimise the potential transmission of pathogens. The risk of cross-contamination is not eliminated by using large quantities of water. Pathogens can be rapidly acquired and taken up on plant surfaces, and natural openings or wounds can serve as points of entry. Once fruits and vegetables have been contaminated with bacterial pathogens or parasites, none of these methods will ensure the safety of the product. Disinfection of water is therefore a critical step to minimize the potential transmission of pathogens from water to produce and among produce over time. In fact, the fresh-cut industry continues to use sanitizers, in spite of their limited direct microbiological benefits on produce, to extend the use of washwater or confer some improvement in quality during early to mid-storage.

CHAPTER 13

CONSIDERATIONS DURING FRESH-CUT PRODUCE WASH

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Three parameters have to be controlled when washing fresh-cut fruits and vegetables: quantity of water used (5 to 10 L/kg of product), temperature of water to cool the product, and concentration of the sanitizer. For the product being rinsed, water temperature must be as cold as possible, and 0ºC is the optimal water temperature for most products. However, when the water temperature is much lower than the produce temperature, the internal gas contracts, thereby creating a partial vacuum that will draw in water through pores, channels, or punctures and be sufficient to draw water into the fruit. Infiltration of 214 Advances in Fresh-Cut Fruits and Vegetables Processing washwater into intact fruit has been demonstrated with several fruits and vegetables.

Washwater contaminated with microorganisms, including pathogens, can infiltrate the intercellular spaces of produce through pores.Water used in the washing of fresh-cut product may become a source of contamination if the washwater contains human pathogens and if there is insufficient wash-water disinfectant present. When the fresh-cut produce is fully submerged in water, for washing or as a means of cooling, they are more likely to have washwater infiltration into the tissues. The reason is that microorganisms, including human pathogens, have a greater affinity to adhere to cut surfaces than uncut surfaces. Growing conditions, particularly conditions such as soil type (sand, muck, etc.), may have a profound effect on washwater disinfectant efficacy as well as the potential for removal of soil particles (e.g., difficulty in removing sand particles from crinkly leaf spinach products). Microbial reduction on produce and water by disinfectant is a concentration-by-time-dependent relationship, and it must be remembered that human pathogens, if present on the surface, may not be completely eliminated by washing (Suslow, 2001). (Suslow, 2001).

Water quality has traditionally been addressed separately in terms of public health impact of waterborne pathogens and outbreaks due to contaminated water.Recently, however, the role of water as a contributing factor to foodborne disease has been explored. Water has been considered the "forgotten food, particularly in terms of its impact as an ingredient of a manufactured food product, and now water source and quality are becoming more recognised as important and potentially impacting components during food production and processing, particularly for fresh-cut produce.

Sanitizing Treatments for Freshâ•,Cut Fruits and Vegetables

Sanitizing treatments are recommended to minimise the potential for growth of microorganisms and contamination of fresh-cut produce. Based on scientific reports, the FDA elaborates guides of recommendations to minimise microbial food safety hazards for fresh fruits and vegetables. The guide published in 1998 defines “sanitise” as “to treat clean produce by a process that is effective in destroying or substantially reducing the numbers of microorganisms of public health concern” (FDA, 1998). This guide also referred to reducing other undesirable microorganisms, without adversely affecting the quality of the product or its safety for the consumer.”

However, in the last FDA guide published in February 2008, the washing of fresh produce has been approached in a different way. In this new version, the guideline states that “washing raw agricultural commodities before any processing of the produce occurs may reduce potential surface contamination. However, washing, even with disinfectants, can only reduce, not eliminate, pathogens if present, as washing has little or no effect on pathogens that have been internalised in the produce.”Moreover, the importance of the maintenance of water quality during washing has attracted much attention as it is now specified that “antimicrobial chemicals, when used appropriately with adequate quality water, help minimise the potential for Treatments to Ensure Safety of Fresh-Cut Fruits and Vegetables 215 microbial contamination of processing water and subsequent cross contamination of the product.” Many of the most recent findings about fresh-cut washing agree with this new approach.

A variety of methods are used to reduce the potential for microbial contamination. Each method has distinct advantages and limitations depending upon the type of produce, mitigation protocol, and other variables. In the last few years, important information has been published concerning the efficacy of washing and sanitizing treatments in reducing microbial populations on fresh produce. A clear and welldocumented comparison of different sanitation methods has been compiled in the Food Safety Guidelines for the Fresh-Cut Produce Industry review (IFPA, 2001). (IFPA, 2001).

This topic is covered in the review by Parish et al. and that of Sapers.The efficiency of numerous chemical and physical methods for assuring the microbiological safety of fresh-cut produce is covered in this chapter, which includes the latest and most significant research findings. This chapter excludes other treatments with lethal effects on plant tissue, such as heat treatment, freezing, drying, fermentation, or those that can be unsafe for consumers.

Traditional methods of reducing microbial populations on produce involve chemical and physical treatments. The control of contamination requires that these treatments be applied to equipment and facilities as well as to produce. Methods of cleaning and sanitising produce surfaces usually involve the application of water, cleaning chemicals (for example, detergent), and mechanical treatment of the surface by brush or spray washers, followed by rinsing with potable water.

The efficacy of the method used to reduce microbial populations is usually dependent upon the type of treatment, type and physiology of the target microorganisms, characteristics of produce surfaces (cracks, crevices, hydrophobic tendency, and texture), exposure time, and concentration of cleaner/sanitizer, pH, and temperature. Bacteria tend to concentrate where there are more binding sites. Attachment also might be in stomata, indentations, or other natural irregularities on the intact surface where bacteria could lodge. Bacteria also might attach at cut surfaces or in punctures or cracks in the external surface. Sapers described that microbial resistance to sanitising washes will also depend in part on the time interval between contamination and washing.

In each country, the regulatory status of washwater disinfectants depends on some particular agencies. The definition of the product used to disinfect washwater depends on the type of product to be washed and in some cases, the location where the disinfectant is used (IFPA, 2002). (IFPA, 2002). In the United States, for instance, if the product to be washed is a fresh-cut produce, the washwater disinfectant is regulated by the FDA as a secondary direct food additive, unless it may be considered Generally Recognized as Safe (GRAS) (GRAS). If the product is a raw agricultural commodity that is washed in a food-processing facility, such as a fresh-cut facility, both the U.S. \environmental Protection Agency (EPA) and FDA have regulatory jurisdiction and the disinfectant product must be registered as pesticides with EPA. A selected list of washwater disinfectants that have been approved by FDA (21 CFR 173.315; 21 CFR 178.1010) is reported.

Sanitizers Containing Chlorine

Over several decades, chlorine-based sanitizers have been widely used to sterilise produce and surfaces within produce processing facilities, as well as to reduce microbial populations in water, and are possibly the most commonly used sanitizers in the food business.Chlorine can be found as a gas (Cl2) or as a liquid in the form of sodium hypochlorites (NaOCl) or calcium hypochlorites (Ca(OCl)2). It is often used at concentrations ranging from 50 to 200 ppm with a contact period of 1 to 2 minutes. Chlorine compounds' antimicrobial action is determined by the quantity of hypochlorous acid (HOCl) present in the water, which is determined by the pH of the water, the concentration of organic material in the water, and, to some extent, the temperature of the water. Above pH 7.5.

Considerations for Sanitizers

Hypochlorite to provide an adequate concentration of active chlorine (hypochlorous acid), the pH of the water should be kept between 6.0 and 7.5. A rinsing step with potable water is required for vegetables. The chemical element chlorine dioxide it has more activity at neutral pH and produces less possibly carcinogenic chlorinated reaction products than chlorine.Sodium chlorite that has been acidified It is more soluble in water than sodium hypochlorite (NaOCl) and has a higher oxidising capacity than hypochlorous acid.Formulations using organic acids Water COD rises dramatically following the addition of organic acid formulations like Citrox and Purac.Tsunami is a good sanitising agent option, but it is more expensive than chlorine. Sanitizers with an alkaline base the high pH of alkaline washing solutions (11–12) and worries about phosphate emission into the environment may be limiting issues for the use of some alkaline chemicals on produce.

Although hydrogen peroxide is GRAS in several food applications, it has not yet been authorised as an antibacterial wash agent for vegetables. Lactoperoxidase enzyme technology the active molecule with disinfectant action is hypothiocyanite, which does not persist in the final product due to its short half-life.

Ozone it is a decent choice for disinfecting washwater and decreasing the need for water replenishment, but it is not a replacement for the washing tank sanitizer. UV-C light source Turbidity has a considerable influence on its efficacy as a washwater disinfectant.

Processes of advanced oxidation

They are efficient for reducing bacteria, chemical oxygen demand, and turbidity in fresh-cut industry water. Water can be reused for a longer period of time, but it is not a replacement for the washing tank sanitizer.High pressure, alternating electric and magnetic fieldsThe fresh produce business is unlikely to adopt these technologies due to the high capital expenditure and the costly process of optimization and water treatment.

Treatments for Fresh-Cut Fruits and Vegetables to Assure Safety There is very little chlorine present as active hypochlorous acid (HOCl), but rather as inactive hypochlorite (OCl^-). It was ineffective as a disinfectant if the concentration of active chlorine (hypochlorous acid) was not high enough. To guarantee chlorine action, the pH of the water should be kept between 6.0 and 7.5. In contrast, if the pH of the water falls below 6.0, chlorine gas may occur, posing a health risk to personnel. If the washwater is not kept generally clear of organic waste, or if the chlorine is not permitted to contact the product for an extended period of time, chlorine will not provide any advantages. The concentration of accessible chlorine influences the solution's oxidising potential and disinfection power. Although minimum accessible chlorine concentrations of 1 ppm are necessary to inactivate microorganisms in clean water, greater amounts are frequently employed for most commodities.

To maintain food safety, chlorination systems must be properly monitored and managed (Suslow, 2001). Chlorine concentrations and pH levels in chlorinated process water should be monitored on a regular basis using test paper strips, colorimetric kits, or electronic sensors. ORP or REDOX, as measured by electrical conductivity between a pair of electrodes, is a technique for determining chlorine levels, notably in water used in dump tanks, cleaning, or cooling (Suslow, 2004).Some automated cooling systems use sensors that detect activity in millivolts to monitor the oxidation reduction potential (ORP) of process water (mV). With chlorine-based oxidizers, the correlations between ORP, contact time, and microbial inactivation are employed to configure the system. An ORP set point of 600 to 650 mV, for example, is often employed. There are easily available commercial systems for in-line monitoring and chlorine administration to maintain water purity and to measure the content of hypochlorous acid on a regular basis (Adeskaveg, 1995). Colorimetric test kits are the most regularly used and accurate for routine examinations. Nevertheless, erroneous readings may occur for postharvest usage due to additional salts dissolved in the water from organic and soil particles rinsed off the item. As a result, ORP is frequently used as a more precise guide to identify unexpected changes in conductivity that may affect free chlorine concentration.

Chlorine may incompletely oxidise organic molecules in process water, resulting in undesired byproducts such as chloroform or other trihalomethanes that are known or suspected to be carcinogenic.Concerns have also been raised in recent years concerning their effects on human and environmental safety. As a result, it is prohibited in some European nations, including

Germany, the Netherlands, Switzerland, and Belgium, for the treatment of minimally processed vegetables. Several countries have also put various limitations on the usage of chlorine. As a result, different chlorine replacements or enhancements to chlorine-based sanitizers have been researched. From a regulatory standpoint, the benefits of effective chlorination as a key instrument for sanitation exceed concerns about the existence of these by-products.

At lower concentrations, chlorine dioxide is more efficient than free chlorine against several kinds of bacteria. Its primary benefits over HOCl are lower reactivity with organic materials and higher activity at neutral pH. As a result, it creates less possibly carcinogenic chlorinated reaction products than chlorine, although having a 2.5 Innovations in Fresh-Cut Fruits and Vegetables Processing times greater oxidising power. Nevertheless, the stability of chlorine dioxide might be an issue. Moreover, chlorine dioxide generating systems are often more expensive than hypochlorite generation systems since they require on-site generation, specific worker safety training, and tight injection systems to limit concentrate leaks and volatilization emissions. Nevertheless, stabilised liquid formulations are now available, which are less expensive and easier to use.

Acidified sodium chlorite is a very potent antibacterial that is created by reducing the pH (2.5 to 3.2) of a sodium chlorite (NaClO2) solution with any GRAS acid (Warf, 2001). This compound's reactive intermediates are extremely oxidative and have broad-spectrum germicidal action (Allende et al., 2008c, 2008d). Acidified sodium chlorite is currently available commercially as Sanova (Ecolab®), a mixture of citric acid and sodium chlorite. This chemical reaction creates active chlorine dioxide (ClO2), which is more soluble in water than sodium hypochlorite (NaOCl) and has approximately 2.5 times the oxidising power of hypochlorous acid (HOCl) (Inatsu et al., 2005). Acidified sodium chlorite in the range of 0.5 to 1.2 g L-1 has been permitted for use on some fresh fruits and vegetables as a spray or dip followed by a potable water rinse (21CFR173.325). Recent investigations have shown that it is as effective as chlorine at lowering total viable and E. coli counts in fresh-cut lettuce, escarole, cilantro, and carrots.

Electrolyzed oxidising (EO) water is a type of chlorination in which a dilute salt solution (1% NaCl) is run through an electrochemical cell with a diaphragm separating the anode and cathode (Guentzel et al., 2008). In this situation, the available chlorine concentration ranges between 10 and 100 ppm, with a high oxidation potential of 1000 to 1150 mv (Sapers, 2003). During the process, chloride ions and water molecules are converted into chlorine oxidants such as Cl2 and HOCl/ClO-. EO water has been shown in experiments to be effective as an antimicrobial decontamination agent for use in food preparation and water purification.

Further Chemical Sanitizers

Because many diseases cannot develop at pH levels below 4.5, acidification of low-acid goods may operate to limit microbial multiplication. Most fruits contain high levels of organic acids such as acetic, benzoic, citric, malic, sorbic, succinic, and tartaric acids, which reduce the viability of infecting bacteria. Some fruits and vegetables, such melons and papayas, have smaller quantities of organic acids, and pH values above 5.0 do not inhibit the development of dangerous bacterial contamination. Organic acids, particularly vinegar and lemon juice, have the potential to be low-cost, easy household sanitizers; however, it is unclear if organic treatments would result in off-flavors in treated produce. For initial sanitation of green fresh-cut food such as escarole and lettuce, they are equally effective as chlorine, the Catallix system, and Sanova (Allende et al., 2008a). Citrox and Purac, on the other hand, are ineffective at reducing the E. coli population in washwater, even at the maximum manufacturer's suggested levels. Moreover, the chemical oxygen demand (COD) of washwater increases considerably following the addition of both sanitizers and did not prevent the transfer of E. coli cells between inoculated and uninoculated fresh-cut lettuce, resulting in cross-contamination.

Other organic acid formulations are commercially available for use as wash-water disinfectants, such as peroxyacetic acid (CH3CO3H), which is actually an equilibrium mixture of the peroxy compound, hydrogen peroxide, and acetic acid (TsunamiTM Ecolab, Mendota Heights, MN). It's a white liquid with an unpleasant odour. Peroxyacetic acid has a wider pH range of activity and is less susceptible to organic materials than sodium hypochlorite. Peroxyacetic acid has well-known antibacterial effects (Block, 1991). This chemical is indicated for use in process water treatment, however one of the major providers claims significant reductions in microbial populations on product surfaces (Sapers, 2003). Nevertheless, following disinfection with peroxyacetic acid, vegetables must be washed with potable water. The addition of peroxyacetic acid to washwater is permitted (21CFR173.315). It decomposes into acetic acid, water, and oxygen, all of which are harmless byproducts. It is a powerful oxidising agent that can be dangerous to handle at high doses, but not at the amounts offered to the produce sector. Peroxyacetic acid is also suggested as a water disinfectant to avoid E. coli cross-contamination of vegetables during processing.

Sodium hydroxide, potassium hydroxide, sodium bicarbonate, and sodium orthophenylphenate (with or without surfactants) have also been shown to be efficient for microbial inactivation in a variety of high pH cleansers (Pao et al., 2000). When high pH waxes used on fresh market citrus were applied to orange fruit surfaces, they demonstrated antibacterial action (Pao et al., 1999). Trisodium phosphate (TSP) has been proven to be effective as a wash to disinfect and minimise Salmonella risk in tomatoes (Zhuang and Beuchat, 1996) and apples (Sapers et al., 1999; Liao and Sapers, 2000) among alkaline-based sanitizers. TSP resistance in *Listeria monocytogenes* has also been documented. Concentrations ranging from 2% to 15% were used in experiments to disinfect fresh and fresh-cut vegetables for 15 seconds to 5 minutes (Zhuang and Beuchat, 1996; Liao and Sapers, 2000; Sapers, 2003). When used in conformity with GMPs, trisodium phosphate is categorised as GRAS (21CFR182.1778) (Sapers, 2003). Nevertheless, the high pH of standard alkaline wash solutions (11 to 12) and worries about phosphate emission into the environment may limit the use of some alkaline chemicals on produce.

H2O2 is GRAS for some food uses, although it has not yet been authorised as an antibacterial wash-agent for vegetables. It leaves no behind since catalase degrades it to water and oxygen (Sapers, 2003). For infected apples, solutions of 5% H2O2 alone or in combination with commercial surfactants can yield significantly larger log reductions than 200 ppm.220 Fresh-Cut Fruits and Vegetables Processing Advances chlorine. Dipping fresh-cut vegetables in H2O2 solution decreased bacteria populations without affecting sensory attributes. Several fruits and vegetables have been treated with H_2O_2 vapour to prevent postharvest deterioration (Ukuku and Sapers, 2001; Ukuku et al., 2001). H_2O_2 is, however, phytotoxic to some crops, producing browning in lettuce and mushrooms as well as anthocyanin bleaching in raspberries and strawberries.

In the presence of peroxide, H_2O_2 and sodium thiocyanate combine to form hypothiocyanite ($OSCN^-$). This technique is known as the lactoperoxidase (LPS) technology, and it is marketed under the brand name Catallix. $OSCN^-$ is the active chemical having disinfectant action. Because of its short lifetime, the $OSCN^-$ molecule does not stay in the completed product. Catallix has just lately been focused in food processing, namely fresh-cuts (Allende et al., 2008a).

Formerly, the usage was examined, but it was always found to be too costly when compared to chlorine. The overall expenses are comparable due to the revolutionary approach of LPS technology. Catallix is permitted for use as a processing aid on fresh-cut goods. Catallix has been shown to be equally effective as chlorine, Tsunami, Purac, and Sanova for initial sanitation of leafy fresh-cut food such as escarole and lettuce (Allende et al., 2008a). Nevertheless, similarly with peroxyacetic acid, using Catallix raises the COD of washwater.

For sanitary purposes, ozonated water and gaseous ozone (O_3) are sprayed to fresh-cut vegetables to reduce microbial populations, prevent browning, and increase the shelf life of certain of these items Ozone is also successful in reducing microbial flora in washwaters gathered from the industry for fresh-cut onion, escarole, carrot, and spinach. Ozone has an oxidising potential that is 1.5 times that of chlorine and 3,000 times that of hypochlorous acid. During water treatment, it decomposes spontaneously through a number of complicated chemical processes including the production of hydroxyl free radicals(OH). When O_3 degrades, it produces oxygen, and it has not been linked to the formation of harmful disinfection byproducts such as trihalomethanes. Yet, if halogens are present in the washwater, O_3 may indirectly create them. Ozone was licenced by the FDA in 2001 for use as an antibacterial agent in gas and aqueous phases for the treatment of raw and fresh-cut fruits and vegetables under GMP (Graham, 1997; Xu, 1999). Common O_3 usage rates for postharvest water disinfection are 0.5 to 4 ppm and 0.1 ppm for flume water (Strasser, 1998; IFPA, 2002). Ozone is largely unaffected by pH between 6 and 8, although its breakdown accelerates with high pH, particularly above pH 8.

Disinfection may still occur at high pH levels since the compound's biocidal effect is quite fast (White, 1992). Ozone treatments have been demonstrated to be beneficial in lowering COD and turbidity in fresh-cut industrial water. One frequently mentioned downside of utilising O_3 as a disinfectant is its high instability, which makes predicting how O_3 reacts in the presence of organic matter challenging. As a result, the strong antibacterial efficiency of O_3 treatments exhibited in potable tap water is reduced in vegetable water.

Treatments to Guarantee the Safety of Fresh-Cut Fruits and Vegetables 221 washwaters from the fresh-cut industry, as the influence of the water's physicochemical properties (mostly turbidity and organic matter) influences the efficiency of the treatments. The cost of treating an O_3 system might be essential to its acceptance and application in the food business. Recent advancements in this technology, such as the formation of smaller bubbles via dissolved O_3 flotation, help the O_3

generating process by enhancing the efficacy of O3, as well as decreasing power consumption and associated operational costs. As a result, O3 technology is a viable solution for fresh-cut industry wash-water disinfection since it reduces the requirement for water replacement and high sanitizer concentrations such as chlorine during vegetable washing.

CHAPTER 14

PHYSICAL THERAPY

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Physical treatments, such as ultraviolet (UV) light, are alternatives to chemicals for disinfection of recycled or recirculating process water and fruit and vegetable sanitization. In reality, the most energetic component of the UV spectrum, corresponding to the UV-C range (200 to 290 nm), is utilised as an antibacterial agent in water and air treatments, allowing for successful disinfection rates when germicidal lamps (254 nm) are used (Chang et al., 1985). The inactivation of microorganisms by UV light is nearly completely due to photobiochemical events that occur within the bacteria. Microbial inactivation is proportional to the amount of UV light absorbed by the bacterium, which is measured in joules per square metre (J/m2) (Lucht et al., 1998). UV technology has been certified by the FDA (21CFR179.39) for use as a food disinfection as long as the right wavelength of radiation is maintained (200 to 300 nm). There are several UV light systems available for water sterilisation. UV light systems leave no chemical residues and are unaffected by water chemistry; nonetheless, their performance as a washwater disinfectant is strongly impacted by turbidity and hence requires clear water to be successful. In reality, the efficiency of UV-C in disinfection is dependent on the existence of particle-associated microbes, which may have a detrimental influence on the disinfection process since UV cannot penetrate particles via solid material transmission. As a result, turbidity, suspended particles, and absorbing chemicals all have an impact on UV efficiency in water disinfection As a result, filtering as a pretreatment should be employed to lower the overall amount of particles. Also, unlike O3, UV-C treatment does not considerably reduce turbidity

Various physical therapies, such as high pressure, pulsed electric fields, pulsed light, oscillating magnetic fields, and ultrasound, have been examined to suppress or remove germs (FDA/CFSAN, 2000). The effects of mild heat and pulsed electric field treatments on the textural aspects of carrots, potatoes, broccoli, and apples have been studied (Lebovka et al., 2004; Stringer et al., 2007), however no evidence suggests that they may be used to control microbes on fresh items. The fresh produce business is unlikely to adopt these technologies due to the high capital expenditure and the costly process of optimization and water treatment. Additionally, using ultrasound to a chlorinated water wash achieves an extra 1 log decrease in pathogens on fresh produce but does not eradicate the danger of pathogens on fresh fruit.

The notion of employing multiple intervention methods is akin to hurdle technology, which employs two or more preservation technologies to inhibit microbial growth in or on foods (Leistner, 1994). Combinations of sanitizers and other intervention approaches, such as heat or irradiation, are likely to produce additive, synergistic, or antagonistic interactions (Allende et al., 2006). Chlorine-ozone combinations, for example, may improve the shelf life and quality of lettuce salads, as well as the water used for rinsing or cleaning the lettuce (Garca et al., 2003; Baur et al., 2004). Applying authorised surfactants to process water decreases water surface tension and may improve sanitizer efficacy.

Advanced oxidation processes (AOPs) are the most recent advancement in sanitising technology, and they employ two or more oxidants at the same time. As a consequence, even refractory organics can be completely destroyed on-site without the formation of sludge or residues. This method is commonly used to treat polluted groundwater, cleanse and disinfect drinking and process water, and remove trace organics in industrial effluent. The most popular method for producing OH is to utilise a combination of catalytic oxidants such as ozone-ultraviolet (O3-UV), hydrogen peroxide-ultraviolet, and hydrogen peroxide-ozone (H2O2-O3). Although all of these reactions can generateOH, the O3-UV combination produces the most OH per oxidant (Gottschalk et al., 2000). As a result, the O3-UV mechanism has piqued the interest of researchers.

The O3-UV technique has also been used to disinfect fresh-cut vegetables, lowering microbial populations, avoiding browning, and prolonging the shelf life of certain of these goods. Additionally, the O3-UV combination is an excellent disinfection solution for industrial vegetable washwater, reaching microbial reductions of 6.6 log CFU/ml (Selma et al., 2008b). Moreover, O3-UV treatments have been demonstrated to be efficient at reducing COD and turbidity in fresh-cut industry water. As a result, water quality may be maintained for extended periods of time and therefore reused.

Heterogeneous photocatalysis, which employs UV-C irradiation and titanium dioxide (TiO2-UV), is also regarded an AOP (Fujishima and Honda, 1972). All of the processes take place at the nanometric scale on the pure silica fibre surface, which is triggered by a specific light. UV irradiation and photon absorption create electron-hole pairs on the TiO2 photocatalyst surface, enabling the generation of hydroxyl radicals (OH) through a reductive route. OH have significantly more oxidising power than O3, H2O2, hypochlorous acid, and chlorine (Suslow, 2001), and have been shown to inactivate bacteria and viruses. Since contaminated disinfection by-products or malodorous halogenated treatments to ensure the safety of fresh-cut fruits and vegetables, heterogeneous photocatalytic technology has been advocated as one of the finest disinfection techniques for water applications. The water does not include 223 compounds generated by the subsequent chloramines interaction with organic materials. It is efficient against Legionella, as well as viruses, bacteria, algae, and other species. Heterogeneous photocatalysis is a powerful disinfection process for vegetable washwaters, lowering microbial counts such as bacteria, moulds, and yeasts.

TiO2-UV therapy was shown to be equally effective as O3-UV treatment for microbial inactivation of fresh-cut produce industry vegetable washwater (Selma et al., 2008a). While COD was unaffected by the treatments, heterogeneous photocatalytic systems were efficient in lowering water turbidity (Selma et al., 2008a). Photocatalytic systems, in contrast to O3 and O3-UV equipment, are simple to install and maintain, and they do not necessitate any additional precautions because there is no risk to the users. Commercial photocatalytic devices, on the other hand, can only cure water. Another downside of employing this method for disinfection is that water turbidity might interfere with photocatalytic inactivation (Kim et al., 2003). As a result, filtering as a pretreatment should be employed to lower the overall amount of particles.

Because of their ease of use and low cost, chlorine-based sanitizers remain the best options as disinfection agents capable of preventing pathogen cross-contamination of produce during washing. Nevertheless, hyperchlorination (the use of high quantities of chlorine) of wastewater with a high organic matter concentration may have significant consequences for product sensory quality, the environment, and human health. As a result, smaller dosages of chlorine-based agents might be employed without losing efficacy in fresh-cut produce washing, lowering the danger of chlorine byproducts.

Furthermore, the implementation of an appropriate wastewater treatment capable of removing undesirable physical, chemical, and microbiological components, such as AOPs, should be chosen with the goal of minimising the effective dose to reduce safety hazards, particularly in the fresh and fresh-cut industries where water reuse practises are used. The use of a competent wastewater treatment system in conjunction with the use of adequate sanitizer to maintain residual antimicrobial activity provides the best barrier for maintaining water quality and eliminating microbes before they attach to produce.

Export of Fruit

The export industry is a growth and development engine. They assist in acquiring not just the most up-to-date gear, equipment, and technology but also items and services that are not offered locally. As a result, it has a highly prominent position on the list of because of their significant contributions to the global pool of foreign exchange, emerging nations' economies are given top priority. The nation's economy depends heavily on export. A consistent and rapid pace of export growth is required to have a healthy trade balance and foreign exchange reserves.

A product that is purchased as from global market is an import, whereas a product that is supplied to it is an export. We can obtain international goods and services through imports at reasonable prices. It enables us to have access to advanced industrial technologies, better health and education systems, and improved transportation services that we may not have had otherwise. In the end, this results in a better life.

While exporting enables us to increase the size of our worldwide marketplaces. It enables nations to employ their resources labor, technology, or capital more effectively. Because various nations have varying amounts of natural resources (land, labor, capital, and technology), some may manufacture the same commodity more effectively than others, resulting in lower prices for consumers.

If a nation cannot effectively manufacture a good, it can nonetheless receive it through trade with another nation that can. In international trade, specialization is referred to as this. In addition to increasing efficiency, international commerce also enables nations to take part in a global economy, which boosts employment rates and raises incomes for both people and the country as a whole. As a result, the economy is stimulated.

Export potential of fruits and vegetables

Because of India's varied environment, various kinds of fresh fruits and vegetables are always available. After China, it produces the second-most fruits and vegetables worldwide. Nearly 15% and 11% of the world's fruits and vegetables, respectively, are produced in India. In 2014–15, India produced 169.48 thousand metric tons of vegetables from 9.54 million acres and 86.60 million gigatonnes of fruits from 6.11 million hectares, according to the National Horticulture Database (NHB, 2016). Gujarat contributes 9.0 and 7.10 percent, respectively, to the production of fruits and vegetables in India (NHB, 2015). India is the world's top producer of guava, papaya, mango, and banana. India is the world's top producer of spice and okra among vegetables, while it comes in second for potato, onion, cabbage, brinjal, cabbage, etc.

Key Factors in Vegetable Production

Having a well-designed plant is crucial for vegetable production, whether it is organic or not. Site selection, water availability and quality, commodity and variety selection, as well as market development, are important elements that should be properly taken into account during the planning process of the farming operation. The surgery is destined to failure if the wrong choice is made with relation to any of these.

Site Selection

All farming enterprises must strive to reduce possible production issues. Particularly for organic growers, this is true. Selecting the right field location is one of the best ways to minimize potential issues. When choosing a field to grow vegetables, three factors should be taken into account: the topography of the field, the kind of soil, and the quantity and quality of water.

Field Topography

The term "topography" refers to the site's general physical qualities, which include things like contour, soil conditions, air and water drainage, and the presence of trees and rock outcropping. The management and yield of crops can be significantly influenced by these traits. Fields with low sections or poor drainage may become flooded during periods of heavy rain. Such circumstances may increase the prevalence of illnesses, lessen plant vigor and productivity, and, in extreme cases, result in plant mortality. Plant diseases, a few of which are transmitted by insects, can thrive in brushy regions or vacant lots and pastures.

Soil type and quality

The physical makeup or characteristics of the soil are referred to as its kind. Sand, sand, and clay are examples of mineral stuff that has decomposed, as well as organic material that has decomposed. Vegetables grow well on sandy loam soils with good drainage. Although a variety of soil types may be used to grow vegetables, most are not well suited to thick clay soils. These types of soils frequently have inadequate aeration and drainage, which might limit root development. As a result, certain soils ought to be avoided. The underlying resource on which all agronomic systems are built is soil. Unfortunately, choosing the right soil type plus soil management techniques takes up much too little time. In organic farming, healthy soil is crucial.

Water

The cultivation of vegetables depends entirely on water. Compared to the majority of other agronomic crops, vegetable crops often demand more average water and more often irrigation. In the majority of Texas, only a few crops can be effectively produced in dryland environments. Even in East Texas, where there is an average rainfall of 45+" each year, crops can face dry spells. In order to produce vegetables, only fields with easy access to a plentiful source of drinking water should be considered. The water supply should really be able to supply the volume needed to meet the maximal demands of the crop that will need the most water when it is planted. The water source must be able to supply the volume needed to meet the maximal demands of the crop that will need the most water when it is planted.

When choosing a water supply for a field location, water quality is just as crucial as water volume. Just under 400 ppm of soluble salts should be present in the water used to irrigate vegetables. Therefore, stay away from water sources that are highly contaminated with harmful components like sodium, boron, or aluminum. A perfect field site with the right soil type cannot compensate for the lack of a sufficient supply of high-quality water. If water of poor quality is to be used, understanding of crop resistance to salt is crucial.

Cause of Losses of Fruit and vegetables

Fruits and vegetables include a wide range of products with a wide range of post-harvest behaviors, although they are always substantially more ephemeral than grains and typically more perishable than roots and tuber crops.

Source of losses

The three most frequent sources of loss were indeed: mechanical damage, temperature-related damage, and pests and pathogens. Rotting caused by bacterial and fungal infections is frequently a sign of bodily harm or deteriorating physiological state. Fruit and vegetables are vulnerable to mechanical harm due to their delicate texture and water holding capacity, which can happen at any point from the farm to the market and not just during storage. Poor harvesting techniques, the use of inappropriate containers to get the product from the field to the market, faulty packed (over- or under-packing of containers), reckless handling of the product or the carton production which it is packaged are all potential causes of injury.

The injuries can come in a variety of shapes and sizes, and they could cause either an instant loss or future degeneration. Dropped produce may split on contact or sustain internal bruises (. Poor handling of the food might result in superficial nibbling of the skin, and fragile fruit, especially green vegetables, is more likely to be crushed. Bacteria and molds can infiltrate injured produce's outer skin, causing fast disintegration and excessive water losses from the wounded area. The consignment's temperature may rise as a result of an increase in respiration rate.

Although perishable crops may tolerate a wide variety of temperatures, they are frequently more susceptible to damage when subjected to temperature extremes. Perishable goods should normally be kept chilled to prevent degradation from starting as soon as feasible. Produce will quickly decay when exposed to extreme temperatures brought on by sun radiation. Extended lens to tropical sun may severely dehydrate plants, especially green vegetables and products with thin skin. In the tropics, food that has been left out in the sun before harvesting frequently reaches temperatures of up to 50°C. Produce that is packaged or transported without enough cooling or ventilation may rapidly spoil since respiration increases with warmth.

Regarding cool storage, low-temperature tolerance is crucial. At temperatures between 0° - minus 2°C, freezing-related injuries are likely. Although some commodities might be able to withstand a little freezing, this will shorten their shelf life since food that has recovered from freezing will be more prone to rot.

Some products, especially those with tropical or subtropical origins, are vulnerable to chilling harm, which occurs when they are exposed to cold but not freezing weather (although these temperatures can go as high as 12–14°C).

The symptoms of chilling harm include discolouration, skin pitting, irregular or uneven ripening, and susceptibility to quick decay. These impacts may not be seen until the product is withdrawn from the chilly environment. In Africa, produce for household consumption is typically not kept in a temperature-controlled environment.

In perishable crops, insect pests seldom provide a serious threat. However, damage can be significant when delicate crops are attacked. Before harvest, insect infestation often takes place in the field, when harm occurs by the larvae tunneling into the product (e.g. fruit fly). If product is kept in storage for a long time, the infestation may continue to spread and become a problem. Rodents and birds can cause losses and damage during storage, much as they do with grains and pulses that are kept in storage. Diseases brought on by fungus and bacteria, which frequently develop as a result of an infection of the crops in the field, cause more severe loss and degradation.

Due to inadequate roads, lack of temperature control during storage and transit, and other factors, processing, such as drying, is sometimes the only way to move fruits and vegetables across long distances. If the final moisture percentage is not properly controlled in this instance, losses might happen. For some items, like chili peppers, mycotoxin contamination might be a problem.

Loss estimates

Since there are no universally established procedures for assessing PHLs of fresh produce equivalent to those for grains, there are few precise numbers available for losses of fruit and vegetables determined using a methodology specified. Individual examples with losses range from 0% to 100% may be found. Even when data have been collected by precise measurement, they might not be very useful because they only account for loss for a single product in a single place under a certain set of circumstances. Furthermore, within a short period of time, the severity of the loss might change greatly.

Loss reduction opportunities

PHLs of fruits and vegetables can develop for a number of causes, some of which are not directly connected to storage, and produce often deteriorates owing to its own physiology rather than to outside forces like insects. In order to eliminate PHLs in fruit and vegetables, it is often essential to develop a unique set of intervention programmed. To get a high-quality product from the field to the market, proper supply chain management which can or can not entail storage must be prioritized.

Economic and Behavioral Factors

Finding optimal practises and technologies and figuring out how to best distribute information and technology to farmers are major topics of debate around PHL. However, policymakers must also think about economic and behavioural aspects that affect farmers' decision-making in order to ensure that such methods and technology are used. Following a discussion of three major adoption barriers, which emphasise the necessity to take farmers' financial limitations and cognitive biases into account when creating policy interventions to reduce post-harvest loss, various design solutions are offered.

Risk aversion

Although PHL prevention solutions are intended to lessen the likelihood that farmers would lose the quality of their crops after harvest, such investments are hazardous from the perspective of a farmers who has no firsthand experience with the a technology and could not completely appreciate its advantages. Since the repercussions of wasting few resources are more severe, a poorer farmer is more inclined to be risk-averse.

FRUIT RIPENING

Fruits acquire their desired flavor, quality, color, palatability, and other textural characteristics during ripening. Ripening is related to compositional change, or the conversion of carbohydrate to sugar. Fruits are divided as senescence and non-climacteric fruits based on how they ripen.

Climacteric

Fruits that continue to mature after harvest are referred to as climacteric fruits since they have entered this phase. Fruits release ethylene throughout the ripening process, and their respiration rate also increases. Fruits that are ripe often cannot endure the rigors of transportation and frequent handling since they are tender and delicate. These fruits are fully developed when they are harvested firm and green, and they ripen close to where they will be consumed. To accelerate the ripening process under regulated temperature and humidity levels, a little dosage of ethylene is utilized.

Non-Climacteric

Non-climacteric fruits do not continue to mature after being picked. Fruits that are not climacteric produce relatively little gas and do not react to ethylene therapy. There isn't a typical rise in the rate of breathing or carbon dioxide generation. Citrus fruits like orange, lemon, mousambi, and minnow can indeed be treated with nitrogen as a de-greening agent to enhance the exterior cooler of skin and market acceptability. The external portion of the peel's green chlorophyll pigment is broken down by ethylene treatment, allowing the expression of a yellow or orange carotenoids pigments.

Technologies for ripening of fruits

The fruit business is faced with a significant challenge due to the lack of quicker, easier techniques for consistent ripening. Almost all ripening techniques, whether traditional or contemporary chemical techniques, have advantages and disadvantages of their own. Today, growers may use a variety of straightforward technologies and techniques to ensure optimum ripening.

Typically, depending on the fruit and the local climate, the time required for edible ripening varies. For instance, mangoes ripen in around 5 to 6 days and sapotas in about 6 to 7 days. Under natural circumstances, the ripening process is significantly influenced by the hormone ethylene, which is generated by the plant.

1. Keeping immature and ripe fruits together in an airtight container is a simple domestic technique used to initiate ripening. Ripening will occur more quickly since previously ripe fruits emit ethylene.
2. Another way is to seal off the space where the fruits are to ripen and use smoke chambers to artificially stimulate ripening. Acetylene gas emits as smoke. This method is used by many fruit dealers to ensure consistent ripening, particularly in citrus fruit like bananas and mangoes. However, the main disadvantage of this approach is that the berries do not develop consistent colour and flavour. Additionally, the product's quality is diminished by the smoke odor's endurance.
3. Another option is to place immature fruits over wheat straw or paddy husk to ripen them over the course of a week.
4. Another method is for some farmers to wipe dry unripe mature fruits after dipping them in 0.1 percent ethrel solution (1 ml in 1 litre of water). Then, a tiny cotton cloth is placed on top of the fruits that have been spread out on a piece of newspaper without touching one another. The fruits will mature using this procedure in just two days.
5. One of the straightforward and risk-free methods is mixing 10 ml of enjoy aspects and 2 gram me of sodium hydroxide pellets in 5 litres of water in a broad range container.
6. This container is positioned within the fruit-ripening chamber, which has been air tightly sealed. Fruits occupy around a third of the space, leaving the rest space open for air circulation. Fruits mature within a period of 12 to 24 hours. Some ethylene-releasing fruits, including papaya and bananas, can also be stored in the same room to save on chemical costs.

Fruit ripening using calcium carbide

In India, calcium carbide of industrial grade is used to ripen the majority of climacteric fruits. The use of industrial-grade calcium carbide for this purpose is prohibited in most nations because it frequently includes residues of phosphorus and arsenic. According to Section 44AA of the PoFA (Prevention of Food Adulteration) Act, calcium carbide usage is also absolutely prohibited in India. When calcium carbide is dissolved in water, acetylene is created, which functions as a synthetic ripening agent. Acetylene is thought to have an impact on the neurological system by decreasing the oxygen flow to the brain. Exposure to poisonous substances like arsenic and phophorus may be extremely harmful to your health.

When done under regulated temperature and relative humidity settings, ethylene, a natural hormone for ripening, is the only approach that is secure and widely acknowledged. Since ethylene is a natural hormone, eating fruits containing it does not endanger consumers' health. It is a contra chemical that may make the fruit's peel perfect yellow (with in case of bananas) while preserving its sweetness and aroma, making it possible to add value to the fruit by making it appear more appetising. It has long been understood that administering ethylene to unripe fruits would only hasten natural ripening till the fruit begins to produce considerable amounts of ethylene on its own.

Methods of applying ethrel

The application method used for ethylene relies on considerations such as cost, ease, and safety. While pure ethylene is explosive and combustible at doses of 3% or more, employing diluted ethylene vapors is safer. The best way to ripen fruit is to place it in an airtight chamber that is kept at a consistent temperature (18–21°C for most fruits, but 29–31°C for mangos).

Cold Storage Conditions of Fruit

The main strategy for increasing the life on fruits is cold storage. When left at room temperature, apples and pears rapidly turn mealy in texture. Fruit has to be refrigerated to keep its quality for longer than a week.

The tree fruits that can be stored the longest are apples and pears, which may be maintained in cold storage for up to four weeks under optimum circumstances and for up to 12 months in regulated environments. Depending on the variety's chilling sensitivity, cold storage temperatures can range from 32 to 38oF. The majority of cultivars can be kept at or around 32 degrees Fahrenheit, however constant temperature monitoring is advised to avoid freezing in spaces with erratic temperatures.

Stone fruit can only be stored at freezing temperatures for one to several weeks, significantly less time than pome fruits. Cherries, apricots, peaches, and plums are all sensitive to chilling damage. Fruit stored in the "death zone," or temps between 36 and 40 of, shows symptoms more quickly. The meat may become mealy, discolored, or transparent.

Stone fruit should be kept in a refrigerator between 29 and 34 degrees Fahrenheit to avoid chilling damage. Cold storage chambers should be cleaned. To sterilize the walls and floors, remove any fruit and containers. Bins should be clean and free of garbage and rotting fruit. Fruit rot is less likely when causes of deterioration are eliminated. Before the commencement of the harvest, refrigeration equipment should be operational.

The ideal temperature for them to sustain is close to 32°F (0°C). Store fruit at a temperature between 36 and 38 (2 and 3 oC) for kinds that are susceptible to cold. Fans ought to be functional and able to keep the air moving. High relative humidity will lessen fruit shriveling and water loss, which are frequent in Red Delicious apples. Fruits will come from out preservation in better shape if these parameters can be satisfied. The best way to keep your fresh produce depends on a variety of factors. As a result, it might be difficult to choose the best storage option to implement.

Benefits of Using Commercial Refrigeration When Storing Produce

Most fruits and vegetables won't remain fresh for more beyond a few days without cold storage. Fresh food starts to degrade as soon as it is harvested, and harmful germs start to grow. Fruit and vegetable spoiling is minimized thanks to the harmful fungi's development being halted by the cold storage units' low temperatures. For several veggies and certain fruits, refrigeration & blast freezing are also common solutions. The temperature range for CRS cold storage units is wide, offering both freezing and chilling choices.

Refrigerated Containers

The temperature range for CRS refrigerated containers is -40°C to +10°C, and they are available in a range of sizes from 10 feet to 45 feet. The majority of cold storage containers are transportable and safe for usage with products. For bigger organizations, mega cold storage are a well-liked alternative. To create a massive refrigerated system, these units are connected with several cold storage units.

Blast Freezers and Chillers

CRS provides quick Blast Freezers for companies wishing to store and deliver frozen produce. Various fruits and vegetables may be frozen at a temperature as low as -40°C. Whether you're wanting to expand your professional refrigeration or are thinking about entering the fruit and vegetable industry, a portable chiller system can prolong the life of your vegetables and fruits in storage and transit.

Cold Rooms

CRS Grade a requirements Fresh product storage and sanitary food processing may both be done in cold rooms. For companies searching for specialized cold storage for your fruits and vegetables, these units are a great option. By prolonging fruit's shelf life, cold storage is included into management methods, which increases market potential. Local, national, and even worldwide export is possible with cold storage. Fruit can also be sold all year round, depending of the planting season. Both of these benefits portend higher industry profitability. Purchase decisions are greatly influenced by fruit look. Maintaining the look, which is thought to be a sign of freshness, sharpness, and sweetness, is made possible by cold storage.

Cold Storage Recommendations for Apples

In addition to ensuring fruit quality, specific storage procedures help reduce damage or harm from the cold. Depending on the variety, mature apples may normally be kept at 32–39°F for 6 months; however, with careful monitoring, this period can be increased to 12 months. While fully matured apples may only be stored in refrigerated temperature for a short period of time (less than a month), partially ripe apples can be preserved for two to three months. Nevertheless, certain cultivars are freezing sensitive, which means that prolonged exposure to low, nonfreezing temperatures might harm them. Apples such as Honeycrisp, Lady Smith, Gal, Fuji, Red Delicious, & Cortland may exhibit chilling sensitivity, which can manifest as conditions like soft scald.

The process of exposing fruit to temperatures of 50°F or 68°F for up to 7–10 days before cold storage is known as delayed cooling or conditioning. The chilling sensitive genotype Honeycrisp benefits from this procedure since it lessens the fruit's vulnerability to chilling damage. Compared to control fruits, there have been reports that a 7-day neural stimulation phase at 50°F significantly decreased soft scald and soggy degradation in Granny smith s to be less than 1%. A nutritional imbalance during preharvest causes bitter pit, some other physiological issue, which causes little brown flesh blisters and also renders the fruit unsaleable. Conditioning treatments have already been commonly found to worsen the incidence of bitter pit.

Cold Storage Recommendations for Peaches

Peaches, by contrast hand, have a far shorter shelf life than apples, making them much more susceptible to deterioration peaches should be stored at a temperature of 32°F, but a variation of 29–34°F is also suitable. However, the physiological problem of chilling damage becomes a worry if peaches are continually kept in cold settings of 36–46°F for more than two weeks. A physiological problem known as chilling damage is brought on by extended exposure to these temperatures—36 to 46°F—but it doesn't manifest until after the ripening process has continued at room temperature. Peaches may exhibit signs including taste loss, browning, bleeding, meatiness, and featheriness in their flesh.

Preparation of Fruits and Vegetables for Canning

Washing

Fruit and vegetables are typically cleaned with water to remove clinging surface microflora, dust, and other impurities. Fruits like peaches, apricots, and others are lye peeled rather of being washed first. On the contrary hand, bathing after peeling should be avoided since it destroys vitamins and minerals. There are other ways to wash, such as soaking or stirring in water, using hot or cold water sprays, etc.

1. In mechanical washers, the product is tumbled or agitated while submerged in water or exposed to water sprays on rotating screens or moving belts.
2. The best way to wash is using high pressure sprays.
3. The wash or rinsing water commonly contains detergents.
4. To disinfect them, vegetables can be placed in a solution of potassium permanganate or bleach (25–50 ppm).
5. The warmth of the water

Sorting and grading

Sorting and grading make ensuring that poor or damaged goods are removed. Along with educated employees who can spot low quality food unfit for canning, an inspection machine can be employed for sorting.

1. To cut down on labour costs, automatic colored sorters can be utilised for sorting.
2. After initial sorting, the fruits and vegetables are evaluated to achieve uniform quality in terms of size, colour, etc.
3. Grading may be performed manually and with the use of grading equipment.
4. Fruits and vegetables are run across screens containing holes of varying diameters for mechanical grading.
5. Mechanical graders come in a variety of forms, including screen graders, roller graders, rope or cable graders, etc. The most popular type of screen graders are those with vibrating screens made of copper and circular apertures.
6. Fruits with soft skins and berries are often assessed by hand.
7. While peaches, apricots, pears, mangoes, and other fruits are assessed after being cut halves or slices for canning, plums, cherries, and olives are graded whole.
8. On the basis of cap size, white button fungi are rated. Only buttons with a cap diameter of up to 2.5 cm and a small head are given an A grade; caps larger than 2.5 cm are given a B rating.

CHAPTER 15

PEELING, CORING AND PITTING

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These are the main unit procedures for canning fruit and vegetables. The technique of peeling and coring is chosen depending on the kind of commodity.

Hand peeling:

Using peeling knives, many vegetables and fruits are peeled and sliced by hand. When peeling fruit with uneven shapes, a peeled knife with a curved blade and a specific guard to control peeling depth can be used.

Mechanical peeling

Pears, apples, carrots, turnips, potatoes, and other fruits and vegetables are peeled using mechanical peeling, coring, and cubing equipment. Peaches and cherries are also peeled using automated peelers.

Lye peeling:

With plenty of water and a heat source, lye is a boiling excellent solvent of caustic soda (Sodium hydroxide) or potassium hydroxide (1-2%) that is used for peeling.

Peaches, nectarines, apricots, sweet orange segments, carrots, and sweet potatoes are just a few examples of the fruits and vegetables that can be peeled through dipping them in heating caustic soda (1-2%) for 1-20 seconds (depending on the lye concentration, temperature/maturity, and nature of the fruit or vegetable), followed by dipping in water.

The meat beneath the peel is separated from the hot lye by a gentle hand-rub of the fruit. To neutralize the alkali, the fruit could also be briefly submerged in a diluted solution of citric acid or hydrochloric acid.

1. Equipment for lye peeling ranges from a basic stainless steel (SS) pan with lye solution with SS baskets acting as cages to a fully mechanized system.
2. The peeling system used in cottage and small-scale canning facilities consists of three stainless steel tanks connected in series, one of which has a steam vent. The second tank has a diluted solution of acid or hydrochloric acid, while the third tank holds tap water.
3. The fruit or vegetables are submerged in the first tank, which contains a boiling, hot lye solution, after being inserted in perforated SS crates, baskets, or cages. The crates are instantly submerged in the second tank to neutralize the lye after the first tank's dipping treatment takes place, and the third tank is used for the final washing.

Cutting/halving/ slicing

Fruits are manually or mechanically cored or halved after being peeled. However, to prevent enzymatic browning, peeled fruit ought to be kept immersed in either water, a 1-2% salt solution, or acid. Before canning, peaches, apricots, pears, tomatoes, etc. are peeled. However, compared to peeled fruits, fruits that have been preserved retain more nutrients.

Processing UV applications

Alternative to conventional thermal processing, ultraviolet radiation (UV) offers a lot of potential in the food processing industry. Pasteurization of juices, post-lethality treatment of meats, treatment of food-contact surfaces, and extending the shelf life of fresh vegetables are just a few of its uses. The use of UV therapy for both solid and liquid meals will be examined in this study along with published research and commercial applications. The author discusses the designs of the UV reactors that had been tried in his lab for the treatment of juice and apple cider.

The use of ultraviolet (UV) light for water treatment, air disinfection, and surface cleaning is widely known. UV light has significant promise in food production given the rising public backlash against chemicals added to meals. UV irradiation enjoys a favorable reputation among customers as a physical preservation technique. UV irradiation is safe to use, according to the US Food and Drug Administration (FDA) and US Department of Agriculture (USDA). The FDA approved the use of UV light as a pasteurization option for fresh juice products in 2000 (US FDA 2000). A 5-log10 reduction in the quantity of the particular pathogen of concern is the performance requirement established by the FDA for fruit and vegetable juice processing.

UV surface treatment

In the food business, UV light is utilized to disinfect surfaces. Applications include the decontamination of conveying surfaces and packaging materials such boxes, caps, bottles, packs, tubes, films, and foils. Decontamination of equipment surfaces in bakeries, cheddar and meat facilities is another application. Although UV light is effective at disinfecting smooth surfaces, there aren't many uses for this technology in the sector of food processing. Its limited utilization may be caused by the narrow variety of commercially available solids-disinfecting equipment.

The majority of kinetic data for microbial inactivation were acquired when the bacteria were suspended in air or aqueous environments. Predicting the rate of surface disinfection using this data is not very useful. The effectiveness of UV radiation relies on the topography or surface structure because complicated interactions between microorganisms and surface substances, like shielding effects from incoming UV, may occur.

Liquid foods and beverages

There is great potential for UV light to lower the levels of microbial contamination in a variety of liquid meals and beverages. Liquid foods, such as fresh juice products and drinks, transmit UV light comparatively inefficiently because they contain of colourants, organic solutes, and suspended debris. This poor transmission reduces the performance efficiency of UV pasteurisation procedures. There are significant differences in the absorbance and turbidity of clear, fresh juices versus juices containing pulp. Orange juice can have absorbances as high as 50 cm-1, but clear apple juice only has a modest absorbance of around 11 cm-1. Juices can range in turbidity from 1000 NTU for apple juice and other pure juices to > 4000 NTU with opaque juices like carrot, orange, and pineapple juice due to the presence of suspended materials.

Reactor designs for UV treatment of juices

The inactivation efficiency can be improved by using the proper UV reactor design, which can lessen interference from some food items' high UV absorbance and viscosity. The location and duration of the microorganisms' occupancy in different areas of the irradiance source can vary greatly, and this has a considerable impact on the flow inside the UV reactor, which in turn has a significant impact on the overall UV dosage administered. For usage in pasteurizing fresh juice, many semi - continuous UV reactor concepts are currently being explored. The first design strategy reduces the route length and hence avoids issues related to poor penetration by using an incredibly thin layer UV reactor. So as to avoid issues brought by by inadequate penetration. Laminar flow and a parabolic velocity profile define thin film reactors. There are non-uniform processing conditions because the liquid's highest velocity, which is twice as rapid as its average velocity, is recorded in the middle The thin film CiderSure plant (FPE Inc., Macedon, NY) and indeed the Taylor-Coquette flow Ultraviolet reactor are the two flow designs (Forney and Pierson 2004). Low-pressure commutated lamps are installed inside a quartz sleeve that runs centrally through reactor in the Cider Sure unit.

Consumers are becoming more knowledgeable of the processes that increase the safety of food and drinks before they are delivered to grocery store aisles, whether it is greater processing or improvements to the pasteurization process. It is becoming more and more common to use ultraviolet light (UV), an electromagnetic radiation with wavelengths between 100 and 400 nanometers, to reduce or eliminate microorganisms from food and beverage items. Shorter wavelengths of this radiation, which is produced by both natural and manmade sources, endanger people more and more.

UV is divided into three groups based on wavelength. The wavelength of UV-A ranges from 320 to 400 nanometers. Sunburns are caused by this radiation, which is also frequently connected to skin cancer. UV-B has wavelengths that range from 280 to 320 nanometers, and it contributes to skin blistering and tanning. UV-B radiation is substantially less potent than UV-A. The shortest wavelength belongs to the third class, UV-C. The radiation used to cleanse wastewater, sterilise food contact surfaces, and disinfect drinking water measures within 100 and 280 nanometers. UV-C between 200 and 280 is inside the "germicidal range," according to the FDA, since it "effectively inactivates bacteria and viruses.

UV has been utilized in the food processing process. Although it is illegal to irradiate organic food, UV-C is used to process various food products, including cereals, cheese, baked goods, frozen meals, fresh vegetables and fruits liquid egg products, juices, and apple cider, among others. Due to federal rules not mandating the labelling of items treated with UV-C, supermarkets and other food sellers might not aware of this, although some states do. It has been demonstrated that UV-C can diminish or get rid of foodborne pathogens including Salmonella, Listeria, and E. coli. The amount of radiation, exposure period, and technology all affect how effective the therapy is. The technique works very quickly and efficiently on juices; it takes fewer than 30 seconds to cure 4,000 litres of juice. However, it takes more than ten years to achieve that level of effectiveness since until recently, UV technology could only be used to cure clear liquids. More thick food and drink products as well as murkier liquids may be possible to be sterilised using UV irradiation as technology advances.

Irradiation of Fresh Fruits and Vegetables

People have been eating more fresh Because of its accessibility and health advantages and freshly cut vegetables and fruit every year for the previous ten years. Unfortunately, the rise in outbreaks and recalls brought on by human disease contamination has coincided with the rise in fresh vegetable consumption. Irradiation successfully eliminates bacterial pathogens on freshly and fresh-cut vegetables, according to recent study. However, store and customer acceptance of this technique remains a barrier to its commercial deployment.

Food irradiation

Foods are not rendered radioactive by irradiation, and neither does it affect their nutritional value or significantly alter their flavor, texture, or appearance. In fact, the alterations brought about by radioactivity are so slight that it is difficult to determine whether a food has already been exposed to radiation.

By reducing or eradicating insects and microbes, food irradiation the application of ionizing radiation to food improves food safety and increases the shelf life of goods. Irradiation can make stuff safer for consumers, much like pasteurizing milk and preserving fruits and vegetables. The sources of radiation used to irradiate food must be under the control of the Food and Drug Administration (FDA). Only after concluding that a sources of radiation may safely be used on foods does the FDA authorize it.

Irradiation can serve many purposes

Prevention of Foodborne Sickness

To successfully eradicate pathogens like Salmonella et al. Escherichia coli that cause food illness (E. coli). Extending the lifespan of food by destroying or inactivating microbes that lead to deterioration and disintegration

Control of Insects: To eradicate insects found in or on imported tropical fruits. Additionally, other pest-control methods that can injure the fruit are less necessary after irradiation.

Delay of Ripening and Sprouting - to prevent fruit from ripening prematurely and to put off sprouting (e.g., in potatoes).

Types of Ionizing Radiation

People come into contact with radiation every day from the natural world and it permeates all aspect of our existence. Radio signals, ultraviolet light, infrared photons, microwave radiation, **ultraviolet radiation.**

Ultraviolet radiation are typical forms of radiation. Ionizing radiations are more potent types of radiation that may create ions, which are electrically charged atoms and molecules. Examples of these radiations include gamma, X, and electron beams. Regarding their impacts on food and microbes, all three forms of ionizing radiation use the same methods.

Ionizing radiation's main target is water. Free radicals are created during the radiolysis of water, and these radicals then damage other substances like the DNA in microbes. Ionizing radiation comes in several forms, each of which has benefits and drawbacks. Gamma and X-rays, for instance, may penetrate materials more effectively than electron beams. But radioactive substances like cobalt-60 and cesium-137 release gamma rays, whereas producing X-rays requires a lot of energy and is very inefficient. When electron beams are transformed into X-rays, the majority of the energy (approximately 90%) is squandered to heat. Despite the fact that electron beam generators may be turned on and off and do not use radioactive materials, electron beams have a limited penetrating ability.

Effectiveness in Inactivating Pathogens

Unpalatable goods have been produced as a result of the high radiation doses applied in an effort to create a sterile or window sill fruit or vegetable commodity. The possibility to include lower irradiation doses, less than 3 kGy, as one of several "hurdles" in an otherwise standard produce processing system is of particular importance in the context of contemporary produce processing. Irradiation successfully destroys pathogenic microorganisms on fresh or fresh-cut food, according to recent studies.

The range of irradiation doses required to achieve a 1-log decrease in bacterial pathogens is generally between 0.2 and 0.8 kGy. To achieve a 1-log decrease, harmful viruses and fungi frequently require 1-3 kGy of radiation, in contrast. The dosages necessary to achieve significant reductions in viruses and fungus are often higher than what is tolerated by the majority of produce.

In terms of food safety, it ought to be noted that, on an annual basis, viruses account for the majority of minor foodborne illnesses (67%), whereas bacterial pathogens are primarily responsible for the majority of serious foodborne illnesses that result in deaths and illnesses (60% and 72%, respectively) (Mead et al., 1999).

Irradiation is thus best suited as an intervention to get rid of the biggest risks to the safety of fruit and vegetable consumers. The pathogen being targeted as the main safety concern, the category of produce being treated, the state of the fruit or vegetable (whole vs. cored, peeled, cut, chopped, etc.), the environment in which it is wrapped, and other commodity-specific factors all affect the antibacterial potential of irradiation.

The methodological specifics of time, temperature, management, and irradiation treatments must go through quality control for the food being treated, much like any other commercial food processing technique. For instance, irradiation techniques created for the removal of E. coli from leafy green vegetables could not meet the necessary standards for quality and food safety if used for the removal of Salmonella form tomatoes.

Pulp Extraction

The pulp as from crown and roots is entirely removed during a polypectomy. The tooth can then be filled with a substance that the body can re-absorb. It is typically done on infant teeth. A polypectomy precedes a root canal, but the tooth is afterwards given a crown or permanent filling. It is frequently carried out on permanent teeth.

Extractors

A tool called an extractor is used to separate liquid from solids. The extractors create a 300G field via centrifugal separation. A liquid extractor was used to remove the liquid. A tool called an extractor is used to separate liquid from solids.

Hydraulic Press

A hydraulic press is a type of mechanical device that transfers energy to metals by bending and deforming them using liquid. It utilises the Pascalian principle. The equipment is mostly used to apply smaller forces higher. According to the Pascal's principle, a static fluid transmits pressure equally in every direction. The mainframe, the power system, and the hydraulic control system are the three primary components of the hydraulic press. In this, a pump that functions like a pump and generates mechanical force is used to apply pressure to a liquid.

Working of hydraulic press

Since it is simpler to regulate the thrust forces with several small rams than one huge ram, this method is used. The working load determines how many rams are needed. The ram is propelled by hydraulic fluid pressure. The high-pressure liquid is supplied by a pump and a hydraulic accumulator. Between the pump and the rams, the hydraulic accumulator functions as a connector. A hydro accumulator stores the rising liquid while the press is motionless. A pressure regulator is utilized when a task requires a powerful force.

A hydraulic press is a tool that uses a cylinder with a movable piston to provide pressure to a contained liquid, which then applies pressure to a stationary diamond or baseplate. A pump pushes the liquid into the cylinder. The hydraulic press is frequently employed in industry to mound metals and do other operations that call for a lot of force. It is produced in a wide range of shapes, sizes, and capacities, from 1 tons and under to 10,000 tones and over.

Components of Hydraulic press

Ram

The number of rams employed in a hydraulic system will vary based on the working load. To better regulate the thrust force, many tiny rams are chosen over a single bigger one. Between the rotors and the pump, there is a hydraulic accumulator that pumps fluid to the ram.

Accumulator

Hydraulic pressure is kept in the accumulator as a fluid and discharged as needed. A hydraulic accumulator is designed as a cylinder with a spring-loaded or pneumatically pressured piston. To maintain a consistent pressure in the accumulator, the pump continually pushes hydraulic fluid into it. The pump serves as the accumulator's inlet, while the machine serves as its output. The pump would have to operate continuously without the accumulator. By acting as a reservoir for the energy required to run the machine, the accumulator helps to prevent this.

Pump

Vane, gear, and piston pumps are the three different types of hydraulic pumps; piston pumps are the most often utilized. Positive displacement pumps, which provide a fixed volume of fluid among each pumping cycle, are used in hydraulic presses. A variable area pump can really be fixed or variable, with the former operating at a set speed and the latter capable of reversing. Because of its effectiveness in high pressurhigh-pressuree hydraulic systems, piston pumps are ideally suited for hydraulic presses. The pump's minimal fluid loss allows it to function at high volumetric levels. Axial, bent-axis, and radial piston pumps are the different varieties.

Cylinders

A hydraulic press's design affects how many cylinders it has. The cylinders' job is to produce the compressive force needed to move the anvil and die. In a two-cylinder design, the ram-carrying cylinder has a larger diameter than the plunger-carrying cylinder, which has a smaller diameter. With two ports for hydraulic fluid input and outflow, cylinders are metal pipes.

A hydraulic fluid-filled conduit connects the cylinders. The hydraulic fluid is put under pressure when the lever in the tiny cylinder pushes downward, applying the produced pressure to the ram.

Hydraulic Press Process

A plane slug is placed beneath the anvil, and pressure from the cylinders powers a ram that pushes the anvil down into in the slug and presses it into the die, showing the mechanical effects of the pressure exerted in the hydraulic system.

Types of Hydraulic Presses

The fabrication, assembling, and manufacture of parts for industrial and commercial items as well as mechanical components heavily rely on hydraulic presses. The frame and metals utilized in their construction, as well as other elements, are what differentiate the various types of hydraulic presses. The capacity of hydraulic presses to apply significant compressive stress to billets in order to flat, shape, bend, stamp, etc bend these billets into patterns and other forms accounts for their widespread usage in manufacturing. With the use of range of dies, the hydraulic press method may be modified to meet a variety of industrial needs.

H Frame Hydraulic Press

A hydraulic press with A H frame (two columns) has a "H"-shaped frame, press chamber, pump, and bolster. H frame presses are employed in a variety of settings, such as production assembly lines, maintenance facilities, and repair facilities. For low volume applications, they have a hand pump available, or air and electricity pumps where dependable operation is needed. The size of the cylinder in AH frame determines how much force is available.

C Frame Hydraulic Press

Hydraulic presses with a single column (or "C frame") feature a body frame shaped like the character "C" with the single arm arrangement. They are exceptionally fast, stiff, function well as guides, and have great accuracy.

They demand less floor area and are perfect for small companies.

Hot break and cold break

Proteins and polyphenols in Hot Break coagulate as during wort boil, ultimately forming large enough flocs (chunks) to separate from solution and fall to the kettle's bottom.

The hot break often happens 5 to 30 minutes after a strong boil has started. In brewing, a cold pause is beneficial. It lessens the effects of chill haze and gives you a much clearer brew as a result. The proteins in the wort are what create cold break. Cold break will occur at 140°F IF the wort is rapidly cooled.

Fruit Powder

Dried fruit that has been finely powdered is known as fruit powder. Fruit powder may be used to flavor almost anything instead of artificial flavoring. However, sweets, where the balance of moisture is crucial, are where fruit powder really shines.

1. Fruit powder made from mango
2. Powder made from pomegranate fruit
3. Powder made from papaya fruit

Mango Fruit Powder

Unripe, tart mangos are cut into slices and sun-dried before being processed into mango powder.

Mangoes are a native of Southwest Asia and are also referred to it as amchur or anchor powder. The majority of people are aware of the exquisite sweetness of mango.

The contrary is true; this powder is quite sour and unpleasant. Although mango powders is not technically a "spice," it can be employed in the same manner as tamarind, lemon, or lime juice is used to enhance sourness.

The fact that this powder is utilized in vegetarian foods, curries, chutneys, pastries, soups, and marinades makes it most closely connected with Northern Indian cuisine.

Pomegranate Fruit Powder

The pomegranate fruit is berry-like in shape and has a leathery skin (husk or peel) that protects many seeds and juicy arils.

Pomegranate seed oil (PSO), which accounts for 65% to 80% of oil from pomegranate seeds, has an outstanding conjugated polyunsaturated acidic taste pumices acid (trienoic acid).

Papaya Fruit Powder

Papayas contain the digestive enzyme papain, which may also be used to tenderise meat. Additionally, papaya has a lot of water and fiber, both of which aid to maintain regularity and just a healthy digestive system.

Vegetable Powders

To provide a potent combination of nutritional advantages, including fibre, vitamins, and phytonutrients within nutraceuticals supplements, vegetable granules can be used alone or coupled with fruit powders. In order to assist prevent cell damage, vegetable powders also include carotenoids, which can counteract free radicals.

1. The tomato
2. Onion

Tomato Powder

To add that familiar tomato taste to any recipe, tomato flour is the ideal addition. It tastes great in smoothies, with soups or sauces, and with eggs. Lycopene, b Vitamins, and many other beneficial elements are abundant in tomato powder, which is produced from dried tomatoes.

Onion Powder

Dehydrated, crushed onion is what is known as onion powder and is frequently used as a flavouring. It frequently appears in salted salt and spice blends like beau monde seasoning. Some variants call for toasting the onion may use white, yellow, and red onions. An industrially produced food item called onion powder has a variety of culinary applications. One can even make their own onion powder.

Fruits and Vegetable Powder Market

Manufacturers in the grocery business are concentrating on adopting health-beneficial food items as a result of the movement in consumer preferences toward healthy products. Food producers are powderizing raw fruits and veggies in order to give healthful food items. Fruit and vegetable powder is used as a key component in the creation of flavorful, creative food items by the food industry and food retail establishments. Fruit and vegetable powders is said to be a great method to add the flavour of out-of-season fruits and vegetables to culinary products. The need for fruits and vegetable powdered will mostly come from North America and the Asia Pacific region in the worldwide market for fruits and vegetables. The majority of the world's fruits and vegetable powders is produced in Asia Pacific.

The growing number of vegans throughout the world is driving up demand with fruits and vegetable powder on the global market. Fruit and vegetable powdered is simple to store and extends product shelf life. Aside from that, this powder may be consumed all year round. Fruit and vegetable flour is used in the foodservice industry to flavour and enhance foods and beverages. Additionally, the usage of this powder aids in regulating the cost of fresh produce at the beginning of the season. Leading businesses are focusing on developing cutting-edge, application-specific goods to maintain their market leadership.

A bright outlook for the nutraceuticals sector is predicted to cause the global market for fruit powder to grow to USD 23.96 billion by 2025. Through functional foods and beverages, consumers constantly strive to meet their nutritional needs. The demand for products has expanded as a result of growing understanding of the significance of micronutrients such vitamins, enzymes, and amino acids.

Customers are more likely to choose convenience foods that suit specific nutritional needs as lifestyles change. The market for fruit powder will be fueled by the aforementioned developments since they have increased demand for nutraceuticals.

Minimal Processing

Minimal processing is an ideal method for conserving food's nutritional value, safety, and sensory quality while avoiding the use of artificial ingredients. Because of customers, the idea of "minimum processing" of food has recently advanced. Ozone treatment, chlorine treatment, and other minimum processing methods are employed to postpone product oxidation in response to customers' increased demand for natural and fresh-like meals. Before the product is put through the process, a number of variables and parameters should be taken into account, including temperature, humidity levels, water activity, redox potential, and others.

Methods for Minimal Processing

Vacuum Packaging

Vacuum packing, which is regarded as modified atmosphere packaging and is a commonly used and acknowledged technology, involves sealing a product inside of an impermeable material after the air has been removed from the membrane. This technique is primarily used to extend food product stability beyond that of typical refrigerated life and to stop the browning reaction that happens on the surface of highly perishable items upon cutting or other damage. The main ingredient needed for the growth of bacteria, yeast, and mound is oxygen. Bacterial growth will be slowed down by eliminating the air which surrounds food.

This packing method is typically used for perishable foods that are difficult to transport and store, and it occasionally need refrigeration since some organisms are resistant to carbon dioxide. This method offers a number of benefits, including a reduction in product shrinkage and moisture loss, meaning that the product's mass won't change until the package is destroyed. The best virgin material is used to make vacuum packing pouches, which have a thickness that is acceptable for handling, shipping, and storage with little care.

Gas Flushing

Different inert gases, mostly nitrogen and carbon dioxide, are employed with modified atmospheric packaging. Gas flushing is the name of this procedure. These gases elevate oxygen from the product's environment in a variety of ways to function as an inhibitor for certain spoilage microorganisms.

Carbon dioxide atmospheric packaging

When employed at particular doses, o2 is already known to have the effect of suppressing pathogens. If this amount is exceeded, it will cause the discoloration of many items, including meat, thus it must only be used within the range between 30 to 40%. When carbon dioxide is absorbed by a product, it might cause the pack to collapse, which can impact the moisture rate. The mixing of carbon under the limits of 35 ppm is employed to solve this issue. Myoglobin is a substance that turns into carboxymyoglobin when it reacts with carbon monoxide, giving it the brilliant cherry color.

Nitrogen packaging

On it’s alone, nitrogen has little to no antibacterial action. Because it must have a very low capacity to dissolve in water and fat as it is subject to changing atmospheric packing, its composition avoids pack collapse. Nitrogen is introduced when packaging displays oxygen at the necessary amount; this prevents oxidative rancidity and the growth of aerobic microorganisms. It is mostly utilized in packing for perishable foods like almonds. Additionally, it serves as a refill gas and maintains packing flexibility. Because it has no negative effects on food, there is currently no set restriction for the utilization of this air in various food packaging.

Argon packaging

The possibility of using argon for customized atmospheric packing has been investigated in a number of labs. Using these findings as a guide, it can be concluded that argon packing is often used commercially in Europe after being tested for a variety of food goods. Argon is used for a variety of purposes since it is significantly denser than nitrogen (1.43 times). Oxygen is transferred at a higher pace than nitrogen. It is discovered that a very little quantity of oxygen survives nitrogen packing, which causes food to oxidise. Argon is employed to solve this issue and entirely fills the gap. By inhibiting the oxidation-causing microbial oxidase enzyme, this gas is also employed to prevent flavour degradation.

Controlled Atmospheric Packaging

It is the procedure used to preserve the composition of the atmosphere. The stability of food in terms of both its quality and safety is largely dependent on various characteristics, including temperature and relative humidity, which must be maintained within their ideal ranges. To protect the stability of container and food, several approaches have been developed, including coating with various films, packing with gases, etc.

Edible films

The exterior layer of food product is coated in order to preserve the product's natural qualities, and edible films are employed to enrobe the product. Food products are no longer consumed right away after being harvested; instead, they go through a number of distinct processes before they reach the consumer, including transportation, storage, handling, and other pressures. These edible coatings are used to stop the nutritional loss that begins as soon as the food is harvested as well as the loss of product stability.

Polysaccharide based coating and films

Several different polysaccharides are utilized in the coating process, including starch, chitosan, cellulose, pectin, and alginate. The films, which operate as a barrier for oxygen, scent, and oils, gave the rigidity and structural integrity, but the disadvantage is that they have a hydrophobic tendency, which loves to store moisture. Because they are closely packed and have a hydrogen linked network structure, they operate as an oxygen barrier.

Active Packaging

To safeguard and preserve food, modified atmosphere packaging (MAP) modifies the gas composition of a package. These packages include modified dioxide (CO_2), oxygenation (O_2), and nitrogen (N_2) compositions to maintain quality and shelf life while maintaining appearance, texture, flavour, and freshness. In order to limit respiration but also biomass loss, regulate microbial spoilage, and maintain food quality, the modified environment contains greater concentrations of CO_2 and lower levels of O_2 than the ambient air. Generally speaking, there are two approaches to maintain the changed environment inside the package: active and passive [1].

Passive MAP

Passive MAP, which achieves and maintains the correct environment using the characteristics of the product and the openness of the packing material, is best suited for breathing food, such like fresh vegetables. The goal of MAP is to maintain a high amount of CO_2 by producing it during respiration. Passive packing techniques are less expensive, but they take longer to achieve the ideal environment and are not suited for temporary storage.

Active MAP

A very new development is active MAP. The desired atmosphere is supplied after air has been removed in a vacuum. This preserves the newly adjusted environment in the box together with additives and appropriate packaging materials. Stakeholders can utilize this type of packaging for a variety of food goods, including processed foods, medications, fresh produce that is breathing and non-respiring animal products. The cost of active technologies is higher than that of passive ones.

Functions of Active Packaging

The purpose of active packaging is to adapt to changes in the environment both within and outside the box. Since the purpose of active packaging might vary with the food product, a variety of technologies are employed in active packaging.

1. By affecting the following processes, active packaging can increase food quality and shelf life.
2. physiology, including fresh fruit and vegetable metabolism, ripening, and transpiration
3. Chemistry, such as the oxidation of lipids and oils
4. Physical processes, such as bread staling and powders caking
5. Spoiling brought on by bacteria, fungus, and yeast.

Moisture Absorbers

One of the earliest applications of active packaging was the removal of extra moisture from containers by adding desiccants to dry goods. Desiccants come in a variety of packaging, including pills, sachets, pouches, patches, and coupons. Desiccants were first used to preserve metals and hardware, not food.

The quality or texture of foods that are sensitive to moisture are affected by the desiccants' removal of extra water vapour. The excessive moisture results in the caking of powders or the softening of crunchy treats like chips, candies, and baked goods. There are two types of moisture absorbers:

Liquid absorbers

In order to avoid microbial contamination and the deterioration of sensory qualities, liquid absorbers is hygroscopic patches or sheets that drain moisture present as a fluid in fresh vegetables, meat, fish, and poultry.

Relative humidity regulator

Desiccants or relative humidity regulators take in water vapour to control relative humidity. These may be salts that melt when heated, such calcium chloride and magnesium carbonate. They are included as sachets or labels in dry goods including snacks, grains, cereals, nuts, and spices that create little moisture.

Moisture absorbers can be any of the following, depending on the substance used:

1. Chemicals including calcium oxide, calcium chloride, natural clay, modified starch, and silica gel.
2. Molecular filters thatcan absorb additional moisture even in hot environments.

Oxygen Management

The most popular active MAPs are those that utilise oxygen removal technology. Packaging sometimes seeks to bring oxygen levels down to 1 or indeed 0.01%.

1. The events that influence food such as oxidation, rancidity of lipids and oils, ripeness and mortality of local food, staling of bakery items, and fostering aerobic microorganisms that can degrade food are all prevented by oxygen scavengers.
2. MAP typically seeks to eliminate O2 from packages, in some situations, such as maintaining the fresh red color of meat or ripening cheese's surface through the mound, a tiny amount of O2 is required to produce the essential biochemical reactions or promote specific bacteria.

CO_2 Scavengers

When the items, like mushrooms, are CO2-sensitive, CO2 removal may be required. In order to prevent the package from bursting, the CO2 created must also be removed. For espresso, cheese, and fresh fruit, CO_2 scavengers are employed.

Some CO_2 scavengers are:

1. Chemicals such as potassium hydroxide, silica gel, sodium hydroxide, calcium oxide, and hydrochloric acid.
2. Biofilms that are gas-absorbent. These are occasionally used as tags for mushrooms and fresh products.
