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REVIEW ARTICLE

Fresh-cut fruits and vegetables – a review

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ABSTRACT: Fresh cut products from fruits and vegetables are in great demand in local market as well as for export. It is very essential and critical to maintain the quality of fresh cut produce from the farmers' field to the consumer. Fresh-cut processing involves careful selection of raw material variety, cultivar, maturity stage, washing, sanitising, peeling, deseeding, cutting, dicing, slicing, pre-treatment (anti-microbial, firming, flavour enhancer, *etc*.), packaging, storage at proper temperature, transportation, *etc*. Maintaining the quality and safety of fresh-cut produce is a challenge as deterioration processes take place due to on-going biochemical and microbiological processes. The combination of sanitizing, packaging environment and temperature need to be optimized to maximize the quality (nutritional and sensory) and safety of the produce. The processors also need to know the spoilage causing organisms, such as pseudomonads, lactic acid bacteria, yeast, moulds, and fungi which can damage the quality of the produce. The knowledge of food borne pathogens and their sources is also important. The processors need to consider all the steps of the fresh-cut produce processing from the point of view of food safety as well as quality of the product.

1. INTRODUCTION

Fresh-cut products are fruits, vegetables or roots that have been trimmed, peeled and /or cut into a fully usable product, and subsequently packaged to offer consumers high nutrition, convenience and flavor while maintaining freshness. Fruit and vegetable* production and consumption have increased in the recent past owing to potential health benefits. Rising consumer demand has come with greater need for convenience and quality. The fresh-cut produce sector has responded to these demands and is currently at distinct stages of development in many countries.

Total production of primary crops, making up of cereals, sugar crops, vegetables, oil crops, fruits and roots and tubers, in the world is approx. 9.1 billion tonnes in 2018. It increased by almost 50% between 2000 and 2018. Cereals, sugar crops, vegetables, fruits and roots and tubers comprise of 33%, 24%, 12%, 9% and 11%, respectively of the total primary crops in 2018 (FAO, 2020). Fresh-cut pineapple, watermelon, pumpkin, jackfruit, *etc*. is commonly retailed in local markets by the vendors. The large size of the individual fruits and the efforts required to clean, peel, slice and cut them are among the major factors which favour fresh-cut produces. Scientific studies on processing, packaging, storage, and safety of fresh-cut produce have been conducted by earlier researchers for many commodities, *viz.,* tomatoes, onions, jackfruit, lettuce, melons, eggplant, pomegranate arils, pineapple, apple, lettuce, carrots, broccoli, cauliflower, durian, *rambutan*, *etc*. Fresh-cut processing involves careful selection of raw material variety, cultivar, maturity stage, washing, sanitizing, peeling, deseeding, cutting, dicing, slicing, pre-treatment (anti-microbial, firming, flavour enhancer, *etc*.), packaging, storage at right temperature, transportation, *etc*. Maintaining the quality and safety of fresh-cut produce is a challenge as deterioration take place due to biochemical and microbiological reactions continue to take place.

Minimally processed fresh-cut produce has huge market potential and can bring in new opportunities for processing

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and value-addition for farmers, entrepreneurs and co-operatives. This paper discusses the various steps involved in fresh-cut processing of fruits and vegetables and their impact on physiological and biological changes in the produce.

2. QUALITY OF FRESH-CUT PRODUCE

Quality attributes of fresh-cut produce are often classified as external, internal or hidden. Consumers mostly look at the sensory attributes such as appearance, colour, flavour, aroma, taste, texture and freshness of the produce. Safety (freedom from physical, chemical and biological hazards) and nutritional value of the fresh-cut produce are also of utmost importance and need complete attention. Fruits and vegetables are well-known sources of useful nutrients in the form of vitamins, minerals, dietary fibre and other phyto-nutrients including flavonoids, carotenoids and phenolic compounds, that may lower the risk of cancer, heart disease and other illnesses (Kader, 2002).

The safety of fresh produce can be compromised by physical hazards such as glass, dust and insects or chemical hazards such as pesticides or microbiological hazards resulting from poor sanitation or bad hygienic practices in the supply chain. Pathogenic microorganisms can contaminate the produce through the soil, contaminated water, badly treated manure, sewage, air, poor hygiene of workers or contaminated surfaces of post-harvest facilities such as produce packages, transport and storage.

Chemical hazards include chemical products (e.g., pesticides, herbicides, insecticides, water disinfectants), prohibited substances (e.g., some pesticides, methyl bromide), natural substances (e.g., allergens, mycotoxins, alkaloids, cyanides and enzyme inhibitors) and toxic metal elements (e.g., lead, cadmium, arsenic, zinc). There is a growing concern about the ill effects of chemical hazards on human health and environment. Chemical hazards may find their way to the fresh fruits and vegetables during production (e.g., phytosanitary products, fertilizers, antibiotics, growth regulators, *etc.*) and post-harvest handling (e.g., phytosanitary products, waxes, detergents, *etc.*). Physical hazards include stones, glass particles, wood, hair, plastic, ornaments and metals which maybe unintentionally introduced to the produce during production and post-harvest operations.

2.1. Pre-harvest and Harvest Considerations

The pre-harvest quality of produce is influenced by the cultivars, genotypes and rootstocks, climate, cultural practices, maturity, and ripening (Kader, 2002). Chemical and biological hazards which may contaminate the produce on the farm, are exceedingly difficult to manage during post-harvest operations, hence, adoption of Good Agricultural Practices (GAP) by farmers is recommended to mitigate contamination risks.

The maturity of fruits and vegetables at harvest decides the quality (aroma, flavour, colour, nutritive value, *etc.*) and has a direct effect on texture of fresh-cut produce(Bourne, 1983).Immature fruit may lack flavour and are susceptible to disorders, on the other hand, overripe fruits are highly susceptible to damage during cutting and are thus unsuitable for fresh-cut processing. For example, harvesting and processing of immature pineapple will not be able to meet the desired organoleptic characteristics, and that of mature/ripe pineapples may not be suitable for cutting and packaging because of loss of firmness. Thus, it is important for the processors to look at the cultivar, maturity (at harvest) and ripening of the commodity to be used for fresh-cut processing. It is important to select the proper cultivars which may yield best organoleptic characteristics and are also suitable for fresh-cut processing, packaging, storage, transport and retailing operations.

2.2. Post-harvest Factors Affecting Quality and Safety of Fresh-cut Produce

The fresh produce after harvest is moved to the processing facility. Temperature, relative humidity, composition of the gaseous environment around the produce and mechanical or physical damage to the produce influence the respiration and transpiration of produce. Maintaining quality after harvest needs proper handling to avoid mechanical and physical injury and the avoidance of chemical and microbiological contamination. Produce must also be stored under most favourable conditions of temperature and relative humidity. Ethylene-sensitive commodities such as leafy vegetables, herbs and watermelons must be stored in the absence of ethylene and away from high ethylene producers.

3. CHEMICAL AND BIOLOGICAL CHANGES IN FRESH-CUT PRODUCE

Cutting of the produce open the cells, releasing the enzymes which act on the substrate in the tissues. Tissue wounding also enhances the ethylene production and stimulates the respiration and phenolic metabolism. Phenolic compounds in turn serve as substrates for polyphenol oxidase (PPO) enzymes which, in the presence of oxygen, eventually lead to the formation of complex brown polymers. The increased respiration rates result in loss of water, carbohydrates, vitamins, and organic acids. Also, there is loss of flavor and aroma on cutting. At the same time, microbial growth at the cut surface also increases as sugars become available, thus accelerating the opportunity for microbial spoilage. It is therefore especially important to manage the fresh-cut produce in such a way to minimize the respiration, colour changes, water loss, *etc.*, till its consumption. Peeling, cutting and other processing operations, cause physiological effects including water loss, membrane deterioration, loss of acidity and speed up the plant tissues' metabolic activities and enhance the fragility of fresh-cut fruit (Yousuf *et al.,* 2018). Positive effect of pulsed light (PL) on the respiratory rate, quality (firmness, color and soluble solid content), bioactive compounds (ascorbate and carotenoid) and total antioxidant activity of fresh-cut ''Tommy Atkins'' mangoes was observed(de Almeida Lopes *et al.*, 2017).

Peeling, slicing, dicing, and cutting procedures, as well as temperature abuse during storage can, however, result in increase in populations of mesophilic aerobic microorganisms (Brackett, 1992; Nguyen-the and Carlin, 1994) associated with fresh-cut products. Temperature plays a significant role in figuring out the nature of the microflora associated with refrigerated fresh-cut fruits and vegetables. Microorganisms associated with fresh-cut fruits and vegetables can vary greatly depending on the produce type and storage conditions. The effects of processing and storage conditions on the survival and growth of pathogenic microorganisms on fresh-cut produce is a public health concern.

Vegetables are susceptible to attack by bacterial pathogens due to their neutral pH. Spoilage of fresh-cut vegetables by bacteria is characterized by brown or black discoloration, production of off-odors, loss of texture and soft rot. Fruit products undergo fermentative spoilage by lactic acid bacteria or yeasts and wilting owing to vascular infections (Heard 2000) and are often affected by fungi because of their relatively elevated levels of acidity (low pH). Moulds are aerobic microorganisms and can be inhibited at carbon dioxide concentrations as low as 10%.

3.1. Spoilage Organisms

The fresh-cut produce needs to be protected from spoilage causing organisms, such as Pseudomonads, lactic acid bacteria, yeast and moulds. Pseudomonads contribute to the spoilage of fresh produce by producing tissue-degrading enzymes such as pectolytic cellulases, xylanases, glycoside hydrolases and lipoxygenase, that degrade the cell walls of the plant tissue. Pseudomonads may also contribute to the yellowing of vegetable products during storage, through the production of ethylene. Lactic acid bacteria are gram-positive bacteria traditionally known as fermentative organisms. These can cause fermentative metabolism and can also grow under anaerobic conditions to cause spoilage such as souring of the product, gas production and slime formation. Psychrotrophic bacteria mainly of the *Listeria* and *Clostridium* species can grow at refrigerated temperatures. Food borne pathogens of importance include *Listeria monocytogenes*, *Salmonella Clostridium botulinum*, *Shigella spp*. and *Eschirichia coli* (especially E coli O157: H7).

Control of food-borne pathogens and spoilage causing microorganisms require preventive measures throughout the supply chain (farm/field, processing unit, storage, distribution, and retail) and it is required that consideration may be imparted to storage temperature, pH, and hygienic conditions(James and Ngarmsak, 2010). Three aqueous solutions of sodium hypochlorite (100 mg/L), chlorine dioxide (10 mg/L), and sodium butyl p-hydroxybenzoate (12 mg/L) and tap water, were used to treat fresh coriander for 15 min. Chlorine dioxide treatment had the least detrimental effects on color, total chlorophyll contents and ascorbic acid contents of fresh coriander. In addition, it also showed a greater reduction in aerobic bacterial counts and maintained the microbial load at lower levels than other treatments during the 10-day storage period (Gao *et al.*, 2017).

4. UNIT OPERATIONS IN FRESH-CUT PROCESSING

The major steps in preparation of fresh-cut produce involves washing and sanitizing, peeling, trimming, deseeding, cutting/dicing to proper size, sorting for defects, drying, packaging, labelling, distribution, *etc*. The major processing steps (James and Ngarmsak, 2010) are depicted in the flow chart given in Fig. 1. These steps need to be conducted with due care depending on the product and the market.

4.1. Harvest

Farm workers must be trained in the selection of fresh produce of sound quality. They must wear clean clothes and follow sanitary measures. Produce must be handled in such a way as to avoid damage and contamination. Workers must be supplied with all equipment needed to minimize damage of fruits and vegetables during harvest, for example sharp harvesting knives, bags and padded boxes.

4.2. Receiving at the Processing Unit

The receiving point at the processing unit shall have staff to check the quality parameters of the produce suitable for processing. The quality parameters such as size, shape, colour, acidity, TSS, defects, *etc.* are checked. The temperature of the produce is also recorded.

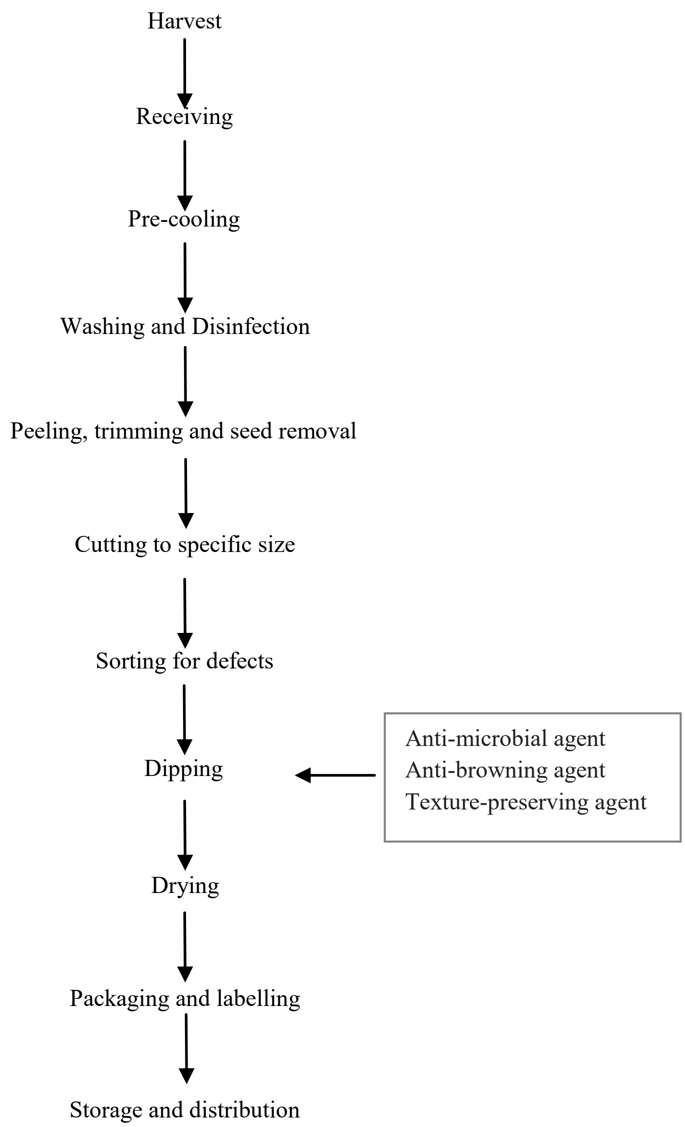

Fig. 1. Typical fresh-cut process flow chart for fruits, vegetables, and root crops.

4.3. Pre-cooling

Pre-cooling is needed to remove the field heat and bring down the temperature of the produce. It shall be conducted as early as possible. Reduction in temperature reduces the rate of respiration and other quality degrading processes. Cooling extends the shelf-life of the final fresh-cut product. Storing under refrigeration is adequate for cooling small quantities of produce. Chilled water baths, forced air cooling, vacuum cooling and packing with ice-water mixtures may be used to cool large quantities in shortest possible time. Temperature may be checked to avoid chilling injury and also appropriately controlled.

4.4. Washing and Sanitisation

Potable water may be used for washing. In small operations, washing under tap in a sink, or use of shallow tanks may be proper. For large quantities, tanks and specifically designed rotary washers are used to handle produce as well as water. Some commodities are placed on moving conveyors and are sprayed with potable water for efficient cleaning. For wash water the following parameters may be used: temperature (0-5^{o}C), pH (4.5-5.5), chlorine concentration (50-100 ppm) and ORP (oxidation reduction potential - 650-750 ppm). During the washing process any defective produce must be removed and discarded. After preliminary washing to remove the dirt and soil on the produce, it is washed in potable water having a sanitiser to reduce the risk of the transfer of microbial contamination during processing (Oms-Oliu *et al.,* 2006)

A sanitising agent or sanitiser is an antimicrobial agent applied to destroy or reduce the number of microorganisms of public health concern, without affecting produce quality and consumer safety. Sanitizers minimize the transmission of pathogens from water to produce, reduce the microbial load on the surface of the produce and prevent microbial build-up in the processing water. Commercially available sanitizers used for fresh cut escarole and lettuce were evaluated by many investigators. The details of the santizers are listed in Table 1 along with their active ingredients, recommended concentration, pH and washing duration (Allende *et al*., 2008).

The highest initial mesophilic reduction was observed after washing fresh-cut escarole with Sanova. Chlorine and Purac showed the highest reductions (2.2 log cfu/g), while the rest of the washing solutions showed a coliform reduction of about 1 log cfu/g. Populations of yeasts and moulds (4.2±0.1 log cfu/g) were significantly decreased ($P \leq 0.001$) by 1.7–1.8 log cfu/g after washing with Sanova and Purac, respectively. The use of sanitizing agents in water is essential to kill microbes before they can attach or become internalized in the produce (Abadias *et al.,* 2011; Artes *et al*., 1999; Cefola *et al*., 2014; Oms-Oliu *et al*., 2006). Ozonated water and peracetic acid treatments were given by dipping cubes in 0.8 ppm of O_3 and 100 ppm of Tsunami 100™ solutions, respectively, for 3 min. Both sanitizers exhibited efficiency in reducing the total microbial counts on melon cubes (< 2 log cfu/g,) Botondi *et al.*, 2016). The efficacy of ozonated water is closely related to ozone solubility, which increases as the temperature of water decreases (Bablon *et al.*, 1991).

4.5. Peeling, Trimming and Deseeding

These are specific for the commodity, pineapple, pumpkin, jackfruit, dalo, *etc.* which require specific peeling, trimming and deseeding operations. In small processing plants, knives are used to trim and peel fresh produce. Large processing plants make use of abrasive peelers and automated trimmers to accelerate the process.

4.6. Cutting

Fresh-cut vegetables, roots and tubers are cut according to the requirement of the consumers and requirement for cooking or consumption. The size and shape of the finished product is decided by the end use identified for each product. Produce may either be chopped, sliced, shredded, peeled, diced or sectioned. Chopping boards and knives are used to create the desired size and shape for finished products. Knives used must be sharp to minimize tissue damage during cutting. Peeling, trimming and cutting operations must be carefully conducted under hygienic conditions to avoid contamination of the produce from equipment, as well as operators. Sanitary conditions shall be maintained inside the working area. Sorting for defects is important. Defective products may also hasten spoilage and decrease shelf-life. Removal of defects improves uniformity of the finished fresh-cut product and enhances shelf-life.

4.7. Dipping

Produce can be optionally dipped in a solution of an acidulant/antioxidant blend consisting of a combination of ascorbic acid/citric acid for example, or in an anti-softening agent such as calcium chloride. In some cases, rinsing of cut fruits and vegetables is carried out with water. The quality of water shall be as described earlier under washing. Browning is in fact the main reason why consumers do not like to buy fresh-cut fruits. The effect of chlorine dioxide and ascorbic acid on enzymatic browning and shelf life of fresh-cut red delicious and granny smith apples was evaluated (Remorini *et al.,* 2015). Fresh-cut kiwifruit and green bell pepper were coated by dipping using five types of treatments (distilled water, ascorbic acid, konjac glucomannan (KG), pomegranate peel extract (PE), and KG + PE), packaged into polymeric film and stored for 8 days at 10^{o}C. The treatment KG +PE resulted in the highest total soluble solid and titratable acidity in fresh-cut kiwifruit, while the maximum firmness in fresh-

Table 1.
Commercially available sanitizers for fresh-cut produce.

Sanitiser	Active compound	Recommended concentration	pH	Washing duration
Chlorine	Sodium hypochlorite	100 mg/L	6.5	1 min
Sanova	Acidified sodium chlorite	500 mg/L	2.7	1 min
Sanoxol 20	Hydrogen peroxide and peroxyacetic acid	20 mL/L	4.3	45 s
Tsunami 100	Peroxyacetic acid and hydrogen peroxide	80 µL/L	5.9	1 min
Purac FCC 80	Lactic acid	20 mL/L	2.7	3 min
Citrox 14W	Organic acids and flavonoids	5 mL/L	3.4	5 min
Catallix	Lactoperoxidase, hydrogen peroxide and thiocyanate	4.0 mg/L	7.7	5 min

Source: Allende et al. (2008).

cut green bell pepper. The weight loss was both effectively decreased in samples treated with KG or KG + PE. All samples treated with KG+PE had significantly higher contents of chlorophyll, ascorbic acid, total phenolic and TAA than others. Moreover, the KG + PE group had the lowest counts of microorganisms in all samples. KG coating incorporated with PE was proved to be efficient in maintaining the physico-chemical and nutritional properties of fresh-cut kiwifruit and green bell pepper during low temperature storage compared with control (Fan *et al.,* 2021)

4.8. Drying

Excess water or liquid on the surface of the cut produce must be removed prior to packaging. Excess water in the finished product encourages mould growth and the growth of other microorganisms resulting in rapid deterioration of the quality. Various manual and mechanical methods have been developed for the removal of excess water from fresh-cut fruits and vegetables. Excess water must be drained from the produce before further drying. Spin-drying baskets, both automated and manual, use sufficient centrifugal force to remove excess water. The cut fruit or vegetable is agitated gently on tilted conveyor shakers with a bottom mesh. The excess water drips through mesh under gravity. Further, if required air drying on trays or conveyors with forced air (dry and cool) is practiced.

4.9. Packaging

Fresh-cut produce is packed in flexible plastic bags/ pouches, thermoformed containers/trays with film overwraps and rigid plastic containers to enable modification of the atmosphere around them and prevent cross contamination during transportation and retail. Packaging facilitates the delivery of fresh-cut products of good quality to the consumer. Cut fruits and vegetables deteriorate more rapidly than intact or packaged products. The minimal processing to which fresh-cut fruit and vegetables are subjected renders products highly perishable, requiring chilled storage to ensure a reasonable shelf-life (Garcia and Barret, 2002).

Modifying the atmospheric composition in which the produce is stored is usually done to slow down the respiration rate, to reduce product metabolism and maturation (Kader *et al.,* 1989), losses in fresh weight and in dry matter (Böttcher *et al.,* 2003). The concentration of oxygen and carbon dioxide inside the headspace is related to the metabolic state of the samples. The levels of oxygen can have other effects on quality, *e.g.* inactivating enzymatic reactions. Because PPO requires O_2 to induce cut surface discolouration, reducing the amount of O_2 in the package of fresh-cut product by vacuum, modified atmosphere packaging (MAP) or gas flushing may reduce cut surface discolouration, although not completely stop it. High carbon dioxide and low oxygen levels inside the pack, extends shelf-life of the fresh produce. Oriented polypropylene (OPP) is generally used in the MAP of fresh cuts. Other packaging films used include perforated, thin, low-density polyethylene (LDPE), monolayerpolyvinyl chloride (PVC) and ethylene vinyl acetate (Bai *et al.,* 2003; Cefola *et al*., 2014; Gomes *et al*., 2012; Gil *et al*., 2002; Chonhenchob *et al.,* 2007, Silveira *et al*., 2011). Normally the permeability of these packaging films is more to carbon dioxide than to oxygen. It is important to conduct studies to select the correct type of packaging materials for each product. Creation of anaerobic conditions inside the package is not recommended. Papaya cubes at maturity stages, 5–45% yellow (more green than yellow) and 55–80% yellow (more yellow than green) were washed with 5% H_2O_2, drained and packaged in PVC trays having five, seven and ten micro-perforations and stored for 19 days. Pretreated papaya cubes, packaged in PVC trays with ten micro-perforations, kept under 4°C had storage lives of 19 days (Jayathunge *et al.*, 2014). The feasibility of using modified atmosphere packaging (5 kPa O_2 +5kPa CO_2) to maintain the antioxidant properties of fresh-cut tomatoes during shelf-life was assessed through storage at different temperatures (5, 10, 15 and 20^{o}C). A storage temperature of 5^{o}C was observed to be appropriate for maintaining the microbiological shelf-life of fresh-cut tomatoes for up to 14 days and also allows the antioxidant properties of tomato slices to be retained over this period, thus reducing wounding stress and deteriorative changes (Odriozola-Serrano et al., 2008). Saxena *et al.* (2008) studied the effect of different modified atmosphere packaging (MAP) techniques for extending the shelf-life of pre-treated fresh-cut jackfruit (*Artocarpus heterophyllus* L.) bulbs (obtained from jackfruits of brownish yellow skin color at optimum ripening stage) kept under low temperature conditions. MAP carried out consisted of 3 kPa O_2 + 5 kPa CO_2 (with balance of N_2) gas mixture flushed polyethylene (PE) bags, polyethylene terephthalate (PET) jars with silicon membrane window on lid and PE bag with air. Based on the sensory quality attributes, the shelf-life of pre-treated jackfruit bulbs packaged in gas mixture flushed PE bags, in PET jars with silicon membrane window and in PE bag were 35, 31 and 27 days, respectively.

The optimal storage temperature for fresh-cut produce is, in general, set as the minimum required to minimize microbial growth while preventing chilling injury. Most of the studies on fresh cut produce have been conducted at a storage temperature range of 4-7^{o}C and relative humidity (RH) levels of 80% to 90% to prevent a buildup of condensates that attracts mould and mildew in the cold room. Four mango cultivars (Kesar, Rajapuri, Totapuri and Ladvo) popular in India were studied for evaluating the consequences of minimal processing on their quality attributes under storage at two different temperatures (5±1^{o}C, 95% RH and 10±1^{o}C, 87% RH) up to 12 days. The evaluated bioactive compounds such as total phenolics, vitamin C and carotenoids were better retained in the samples stored at 5^{o}C as compared with that of 10^{o}C. Also, the storage of fresh-cut mango cultivars at 5^{o}C showed lower water loss and microbial contamination (Sharma and Rao, 2017). Use of ozone in combination with polypropylene packaging provided the best solution to maintain the quality of melon cubes for up to 5 days of storage at 4°C Botondi *et al.,* 2016). Pulsed light treated fresh-cut mangoes stored for 7 days at 6^{o}C temperature were observed to be better preserved (de Almeida Lopes *et al.,* 2017). Amaro *et al.*(2012) studied the effect of oxygen on aroma volatiles and quality of fresh-cut cantaloupe and honeydew melons stored under a high oxygen passive modified atmosphere packaging (MAP) or reduced oxygen controlled atmosphere (CA; 5 kPa O_2 + 10 kPa CO_2 and balance N_2) for 14 days at 5^{o}C. Lower O_2 availability under CA conditions likely suppressed some of the esters relevant to the aroma of fresh-cut melon. The O_2 levels in the gaseous environment inside the package was observed to be more important in determining aroma than other quality attributes of fresh-cut melon, and high O_2 levels may be required to reveal desirable aroma compounds. Packaging material, type, storage environment, temperature, relative humidity, *etc*. play an important role in maintaining quality and safety of the fresh-cut produce.

5. CONCLUSIONS

The procedures and safety concerns must be given consideration at each step of fresh-cut processing of fruits, vegetables, roots and tubers. The pre-harvest and harvest conditions including the maturity of harvested produce are crucial factors for maintaining the quality of fresh-cut produce. Suitable conditions like optimum temperature and relative humidity need to be maintained to reduce spoilage of fresh-cut produce due to growth and proliferation of the microorganisms during storage and transportation. Packaging plays a significant role to reduce the spoilage of the fresh-cut produce and maintain its quality till its consumption within the stipulated period. The fresh-cut produce must be managed in such a way to reduce the respiration, colour changes, water loss, *etc.* till its consumption. Scientifically planned studies need to be conducted to establish and validate the correct parameters for each commodity according to the agro-climatic regions.

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