Chapter

Fresh Cut Fruits and Vegetables Disinfection Pretreatment: A Novel Approach to Extend Fresh Cut's Shelf Life

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Abstract

Fresh cut fruits and vegetable have gained penetration and popularity since last few years. These fresh cut commodities are in great demand among the consumers as these are ready-to-eat fresh and provide all essential nutrients. The increasing trend in fresh cut produce tends to increase the investment in research and development to address various issues regarding the product supply, refrigeration, packaging technology, processing and shelf life extension. Cutting and peeling causes physical damage to the raw fruit and vegetable that make them more perishable. In these review latest developments that plays the key role in extending the shelf life of the fresh cut are discussed. These technologies help in reducing the microbial load over the fresh cut without much altering the physicochemical properties. Future researches should consider various combined technologies which allow better preservation as well as supplemented with nutritional factors.

Keywords: fresh cut, sodium hypochlorite, shelf life, microbial inhibition, physico-chemical

1. Introduction

India ranks second in fruit production after China with production of 98,579 ('000MT) under 6648 ('000Ha) production area (NHB, 2018–2019). There is marginal rise of India's horticulture produce in 2019–2020. According to the estimation of ministry of Agriculture and farmer's welfare, total horticulture production in the country stood 310.74 million Tonnes in 2018–2019. This is marginal higher than the production in 2017–2018. 97.97 million Tonnes of fruit production are estimated compared to 96.45 million Tonnes in 2017–2018. A major contribution to total fruits production of India is contributed by Punjab with 94.80 ('000MT) under production area of 2001.69 ('000Ha). Presently Kinnow, Guava, Mango, Pear, Sweet Orange, Litchi, Peach and Ber are major fruits; while Limes/Lemons, Amla, Grapes, Plum, Banana, Pomegranate, Phalsa, Sapota, Papaya etc. are the minor fruits grown in the

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Punjab region. Fruits are a great source of nutrients, dietary fiber, minerals, vitamins and energy and its consumption is linked to reduce the risk of cardiovascular diseases and flabbiness. Fruits also are the rich source of phytochemicals and other phenolic compounds that function as anti-inflammatory agents, antioxidants and phytoestrogen [1]. Intake of vegetables and fruits has been increased as today's society is becoming more concerned about health and role of raw fruits and vegetables for improving and maintaining consumer and human health. Increasing demand of nutritious and healthy products, fresh produce is always at the priority of the consumer list because of natural nutritious quality, flavors and freshness. The International Fresh-cut produce association (IFPA) defines as fruits and vegetables that have been trimmed and/or peeled and/or cut into 100% useable product that is bagged pre-packaged to offer consumers high nutrition, convenience and flavor while still maintaining its freshness. The fresh-cut vegetables and fruits are in great demand among the consumers as these are ready-to-eat, fresh and nutritious. Today, people are replacing unhealthy junk food with fresh cut vegetables and fruits. The increasing trend in fresh cut produce tends to increase the investment in research and development to address various issues regarding the product supply, refrigeration, packaging technology and processing equipment. Fresh cut produce is gaining popularity among the consumers which lead to the availability at the retail level also. This results in the expansion of industries favoring production of fresh cut fruits which accelerates the quick services at restaurants and in retail shops. There are many produce of fresh vegetable and fruits in the market like fresh cut salads, fruits and vegetables in the market. Many industries are committed in developing the products so as to continue delivering the reliable product in the market. Fresh cut vegetable salad dominate among the minimally processed fresh cut produce but as the popularity of fresh cut fruits among the baby boomers and young generation of the society will probably overtake the sale of fresh cut salad in coming years. There are certain cons related to the productionof fresh cut produces. The process of damage can be defined in two major patterns which directly or indirectly influence each other in their production. Physiological spoilage is caused due to metabolic and enzymatic activity of the plant tissue and microbial spoilage is caused due to proliferation of microorganisms. Cutting and peeling of fresh raw fruit causes physical damage to the fruit and them more perishable than the intact fruit [2]. The quality factor of fresh cut vegetables and fruit product is analyzed by the consumer is the combination of properties or characteristics that decide their value to the consumer. It is often assumed the "if it looks good, it tastes good." Quality of fresh cut fruits is usually determined by the various properties which include nutritive value, flavor, appearance and texture. On accessing the product quality consumer assess product appearance and probably the color of the product [3]. Quality of fresh intact fruits depends upon the cultivator, pre harvest and harvesting methods, handling methods while when the factor of "fresh-cut" fruits come into play it renders the shelf life of the produce because of highly perishable nature. Fresh cut salads are gaining popularity in the market as various negative effects are addressed during processing while on the other hand fresh cut fruits do not show exceptional growth due to its biochemical and physiological phenomena which accelerates the perishable nature of the fruits and vegetables. Major factor that affects the quality of the fresh cut methods of preparation which includes types of tools used, surface area and size of the cut slices, type of water used for washing and handling as well as storage conditions which includes humidity, packaging, maintaining optimum temperature and sanitation conditions.

Proper washing/cleaning of fresh-cut product right after cutting is the most important step in fresh cut production to reduce the pathogenic micro flora from the commodities [4]. Food safety guidelines (FDA) for the fresh-cut product industry usually stipulate a washing or sanitizing step to eradicate pesticide residue, dirt and microorganisms responsible for decay and quality loss. The effectiveness of the washing pretreatment depends upon the quality of the water, pH, temperature of the operation, type and concentration of the disinfectant and contact time with the commodity. The product should rinse and washed with the water visually free from dirt, dust and other debris [5]. The U.S. Food and Drug Administration (FDA) guide to reduce the microbial count on fresh-cut vegetables and fruits to safety level point out that water quality is the very important step on fresh cut processing (FDA/CFSAN 2008). It is also considered that using sanitized water for washing purpose reduces the initial microbial load on the fresh cut produce is accountable to extend the shelf life of the produce [6]. So, there is a need to give main focus on the disinfectant washing to decrease microbial count on raw vegetables and fruits, being an economic technique to enhance the fresh cut's shelf life. Additionally, use of chemical disinfectants along with cold refrigeration storage is an effective way to extend the shelf-life of fresh-cut fruits up to a reasonable level. Further, there is a need to test for various disinfectants to evaluate their efficacy in reducing microbial load over the fresh cut fruits and the best packaging material to be discovered to enhance the shelf life and quality of fresh-cut fruits. Being the most economic and easy method to conduct, disinfectant pretreatment washing of the cut fruits with an optimum disinfectant following an optimized process conditions provides the farmers to opt for the new technology to establish the Fresh cut market in Punjab. This book chapter reviews the various techniques to disinfect the fresh cut fruits and vegetables with novelty lies in the process parameter optimization including type of disinfectant, concentration of disinfectant, pH and dipping time for disinfection will help the fresh cut industries to opt for the process technology to enhance the shelf life of the fresh cut fruits and vegetables.

2. Global trends of fresh cut produce

Healthy and nutritious foods are of critical importance among the young population of the country. Vegetables and fruits are imported round the year to meet the demands of the country. With increased dining away from home, fresh cut products are taking an ever-increasing role because of time saving in cooking of other food materials. Fresh-cut vegetable and fruits are the prime rapid budding food categories in United States superstores. The requirement of fresh cut commodities is also increasing being a healthier preference over the fast food sectors. The freshcut manufacturing industries are flourishing in various European nations with the United Kingdom, France, and Italy as share pioneers. In the Eastern nations, Europe is among the nations with highest advancement in fresh cut industries. In the above stated developed countries, fresh cut vegetables and fruits are developed at the industrial scale but in India and other developing countries, the production is yet at a small scale. Now with the rising awareness and concern in this category of commodities, there is a massive opportunity of fresh cut market in the emerging countries [7]. Small scale industry also plays a significant share in supplying packages for fresh cut commodities to the developing countries as per the demand by the consumers. Small scale businesses and small vendors are the fundamental distributors of fresh cut commodities in most emerging nations. In 2006, 27% of freshcut produce in the United States was sold in the food service sector, while 73% was sold in retail. Freshcut produce sales increased in value from US$3.3 billion in 1999 to US$15.5 billion in 2007 [8]. Fresh cut packed salads and vegetables showed a growth trend in 2008, while sales in fresh cut fruits declined. Fresh cut organic salads are now being mainstreamed across the United States and feeding consumer desire for healthy food. Fresh cut commodities are widely available in restaurants and retail outlets in US. Fresh cut fruits and vegetables are sold in parts of the Asian countries as well. Fresh cut vegetables are in greater demand as compared to fresh cut fruits in Thailand [9]. With this growing demand of fresh cut commodities, Thailand is likely to show a continued growth trend. Recently in India, German Food Company which deals with fresh cut fruits and vegetables has formed a joint venture with exotic fruits importer IG interventions and launched the sliced fruits packs. In 2017, the fresh cut and ready-to-eat product trend has grown by 4% in both volume and value compared to 2016 industrial brand have increased their share by 8% despite their market share already being 40%,"explains AIIPA fresh-cut president [10].

3. Quality of fresh cut fruits

Quality is a combination of characteristics that determines the value of produce to the consumer. Fresh produce is expected by the consumer without any defects having optimum maturity, physicochemical characteristic and must be in fresh condition. The condition of fresh vegetable and fruits relates to their sensory quality, general appearance, nutritional quality and flavor [11]. Overall quality characteristics impacting the fresh cut fruits and vegetables are compiled in **Figure 1**. Consumers judge the quality of vegetables and fruits on the basis of their appearance and firmness (external attributes). Important aspect to be considered during the preservation of fresh cut produce is tissue color and control of surface browning and discoloration. Polyphenol oxidase (PPO) is the enzyme is responsible for the oxidative browning of the surfaces

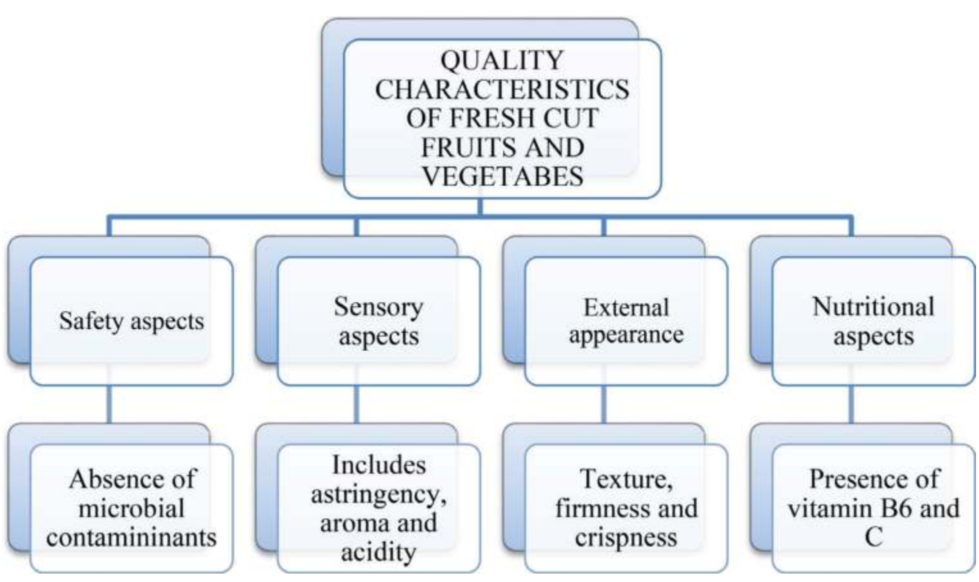

Figure 1.
Quality characteristics of fresh cut fruits and vegetables.

of fresh cut produces. In this reaction, phenolic compounds present in the fruits and vegetables get converted into dark colored compound in the presence of oxygen after coming in contact with environmental conditions. Extent of browning varies by growing conditions, cultivator and commodity characteristics. Several researches have been done to reduce the PPO-mediated discoloration. Usually a simple visual, appraisal of appearance and quality, hopefully objective is desired. A detailed scale to analyze the color quality of both fresh cut and whole fruit is also followed [12]. Consumer often buys the product for the first time based on appearance or impulse. Apart from this, other intrinsic factors such as texture and flavor also plays role in determining the quality. Flavor is comprised of aroma and taste which mainly relates to sugar, acids, salts, bitter compounds and volatile components. Flavor in fruits and vegetables arises from numerous biosynthetic pathway and wide range of aldehydes, alcohols, esters, ketones, lactones, sulfur and nitrogen containing compounds.

Volatile compounds play major contribution to impact the aroma in fruits such as banana, apple, pear, guava, papaya, strawberry and melon. During the storage of fresh cut produces, flavor losses that act as the direct consequence of senescence. Flavor changes occur during the storage of fresh cut fruits and vegetables may affect the consumerpreferability towards buying of fresh cuts. Consumer generally considers flavor as the most important attribute for fruits and vegetables, but textural defect in interaction of flavor also responsible for the consumer rejection. Texture comprises of both mechanical and structural properties of the food, as well as sensory component in mouth and hand, all of which can be measured by several nondestructive and destructive instruments or objective method [13]. Subsequent purchases by consumers are, however, depends upon their eating experience (taste, aroma experience attribute or texture intrinsic).

Other quality parameters like nutritional and safety attributes also influence consumer decisions on making repeated purchases of the commodity. Fruits with highest quality should be used for the processing of fresh cut commodities. Fruits and vegetables act as the major source of vitamins, fibers, minerals and carbohydrate. There are certain metabolites such as anthocyanins, phenolic acids and flavonoids are obtained from fruits and vegetables which plays integral part in human metabolism and also assumed to beneficial for human health due to its biological properties including antiviral, anti-inflammatory, antibacterial, antioxidant function [14]. These above mentioned components are considered to be highly beneficial in curing certain diseases such as coronary heart diseases, osteoporosis, stroke, and hypertension. Daily intake of 400 g of fruits and vegetables is recommended by the world Health Organization in 2003 [15]. Processing of raw fruits and vegetables results in alteration of nutrients. After cutting of the fresh fruits and vegetable, the antioxidant capacity of the produce may increase (celery, carrot, parsnip, potato, white cabbage, sweet potato) [16] or decrease (potato, melon, zucchini, cabbage) during storage. Carotene and Vitamin C content decrease very little during short term storage of fresh cut fruits [17]. However, Vitamin C and ascorbic acid content usually decreases after cutting, especially during long term storage [18]. Safety is also the major component for maintaining the quality aspect of fresh produces. Safe food should be free from physical, chemical and biological hazards. Physical hazard include glass, stones, plastic, hair, jewelry and metals which may be intentionally or unintentionally get into the produce during the production process. Chemical hazards include natural substances for, e.g., mycotoxins, alkaloids, allergens and enzyme inhibitors, chemicals like pesticides and toxic elements like lead, arsenic, zinc, and cadmium. These elements affect the human health more rapidly as compared to biological hazards. This chemical hazard enters into the fruits and vegetable during production process and postharvest handling. Biological hazards are caused by the pathogenic microorganisms. These microorganisms cause intoxication and food borne infections when consumed. Microbial population which may be insufficient to cause food spoilage but may be sufficient to cause illness in human beings on consumption of fresh produces. Thus, the fresh cut vegetable and fruits which seems perfect in appearance is not guaranteed to be microbiologically safe. These pathogenic microorganisms may contaminate the fruits and vegetables through irrigated water, soil, badly treated manure, sewage and poor worker hygiene or through poor postharvest handlings. There are many factors that impact on the quality of fresh cut produce is described below:

4. Factors impacting quality of fresh produce

Factors impacting fresh produce may be categorized as physical, chemical or microbiological factors (**Figure 2**). The quality of the fruits is influenced at various stages from growing to harvesting and even during storage. The quality of the produce before its harvesting is influenced by the genotype, road stock, climate, cultivars, cultural practices, maturity and ripening [19]. So, it is essential to choose the appropriate cultivars to assure the quality characteristics of the fruit destined for fresh cut processing. Climatic conditions and cultural practices also affect the nutritional quality of the fresh produce. The growing season and location influence

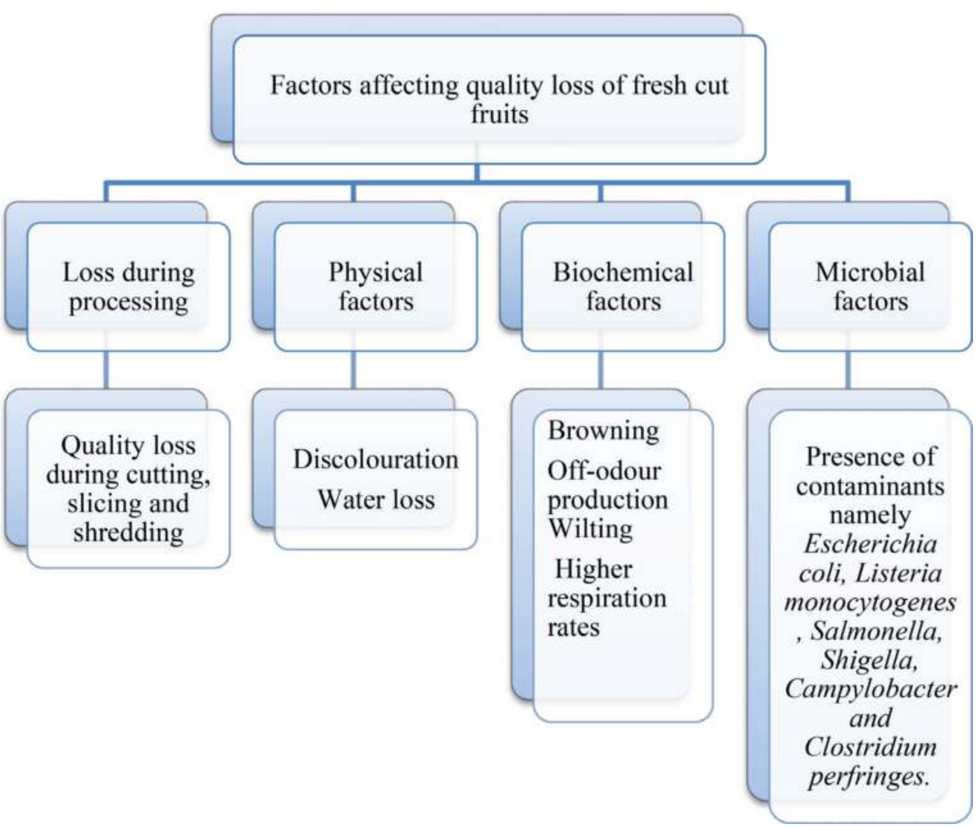

Figure 2.
Factors involved in quality loss of fresh cut fruits.

the level of carotene, riboflavin, ascorbic acid and other nutrients. Low light intensity results in the low levels of ascorbic acid in the plant tissues. Heavy rainfall results in mechanical damage to fruits which make them prone to be attacked by the microorganisms. Agricultural practices like trimming and pruning increases the crop load and size of the fruit. Nutrient composition of the soil has an immediate impact on the fruit texture [20], taste and appearance. [21] studied that deficiency of calcium in soil will result in tissue softening after harvest. Contamination of the produce starts right from the fields which results in outbreak of food borne illness [22]. Use of raw manure to edible crops and contaminated water can transfer pathogens to the crop resulting in diseases. Harvest techniques also affects the fresh produce quality. Maturity of fresh fruits at the time of harvest directly effect on texture. Immature fruit contain insoluble pectic substances of high molecular weight known as protopectin. On ripening of fruit, these pectin polymer decreases and water soluble pectin are formed. This pectin imparts the characteristic textural changes in the fruit leading to a soft and mushy consistency [23]. Over ripened fruits are generally susceptible to damage during cutting and thus, are not suitable for fresh cut processing. For the fresh cut produce, fruits are harvested at the optimum maturity stage in order to ensure the best eating quality produce. Fruits like banana, guava and papaya continue to ripen even after harvest by exposing them to ethylene. Fruits like pineapple, litches, oranges and muskmelon are harvested mature because no ripening and flavor development occurs after harvest. Fresh produce quality and safety is affected by the post harvestmanagement factors. Management of storage conditions like relative humidity and temperature and handling of the produce influence the quality after harvesting. Temperature, relative humidity, the composition of the gaseous environment influence respiratory and physiological processes. Chemical and microbial contamination compromises the safety of fresh produce. Microbial contamination can be transmitted through improper cultural practices, through contact with unclean surfaces and soil, unhygienic working conditions composition of gases in environment and physical or mechanical damage to the produce. Loss of vitamin C accelerates by the mechanical injury and can and can increase the susceptibility to spoil by the microorganisms. Proper handling is required after harvesting to avoid physical and mechanical injury and the avoidance of microbiological and chemical contamination. Vegetables and fruits must be stored under optimal relative humidity and temperature conditions. Ethylene sensitive green leafy vegetables, watermelons, herbs must be stored separated from high ethylene producers like peaches, tomatoes.

Apart from all the risk factors microbiological safety is the major concern in the fresh cut industries. Many factors may be involved in the epidemiology of the produce associated diseases. In case of fresh cut produce risk can be divided into two categories. First one deals with the conditions or factors contaminating fresh produce with the microorganism during cultivation or harvesting [24]. These include use of contaminated water for irrigation, poor agricultural practices, and use of chemical sprays in irrigation water, application of improperly composted manure and lack of training and good personal hygiene among the workers. The second category of microbial risk is at the cutting and slicing operations in the industry. Internal tissue of the fruit is generally free from the comtamination due to waxy and outer peel. However, cutting and slicing breaks the physical barrier and allows the juices to come out from the internal tissue on the surface of the fruit. This juice contains nutrients which accelerate the growth of microorganism. Surface exposure results in the growth of many potential contaminants and pathogens on cut surfaces [25]. Microbiological risk factors have been determined by the researchers and include the following:

several pathogens (e.g., *Listeria monocytogenes* and *Aeromonas hydrophila*) are psychotropic and can grow at temperatures used to store the fresh cut produce, there is no kill step(like cooking) in the process to eliminate the potential microorganism, the longer shelf life (0–14 days) which is common, due to sophisticated packaging and good temperature control may provide sufficient time for pathogen to grow. Modified atmosphere may inhibit the growth of spoilage organism, but certain organism like *Listeria monocytogenes*, survive and thrive under such conditions [26].

Quality of fresh cut can be maintained between the harvesting and processing. Fruits are harvested when they reach maturity. Methods of harvesting, extent of handling, temperature, storage time influence the quality of fresh produce. Trained labour should be employed so as to prevent the produce from the damage. Fruit and vegetables which are damaged by the insects, animals or by any other physical damage are not fit for the production of fresh cut produce as these are more susceptible to microbial contamination. Fresh produce should be handled properly to assure the safety and quality. Pre cooling of harvested produce is done to reduce the field heat, reduces the impact of ethylene on ethylene sensitive produce, prevent wilting, prevent the quality loss by suppressing respiration and enzymatic degradation, and slow down the microbial activity.

In the preparation of the fresh cut produce highest priority is given to the safety the product. Washing of raw fruits and vegetables eliminate number of pathogens but fail to eliminate human pathogen. So, it is essential to evict the pathogen on produce with various physical and chemical treatments supported by food safety programmes including Hazard Analysis Critical Control Point (HACCP), Good Manufacturing Practices (GMPs), Good Agricultural Practices (GAPs).

5. Latest technologies to ensure safety and to increase shelf life of the fresh cut fruits and vegetables

5.1 Chemical treatment

5.1.1 Dipping in disinfectants

Washing of the fresh produce is done to remove dirt and to reduce the microbial contamination during processing. Sanitation and post harvest handling effects the microbial population on the quality of fresh cut produces. Washing of vegetables and fruits results in insignificant decrease in microbial population. Use of disinfectants and sanitizers like peroxyacetic acid, chlorine, hydrogen peroxide, sodium chloride or ozone can do reduction to 1–2 log units in the initial population of the microorganism on the fresh produce. Chlorine is used as the most commonly used sanitizer for washing purposes. Chlorine concentration from 50 to 200 ppm is used for washing fruits and vegetables [27]. Despite chlorine is used as the disinfectant for decontamination, it has been in several European countries due to chemical hazards associated with it [28]. There are many alternatives used to chlorine nowadays. Chlorine dioxide (ClO_2) is approved to use in flumes water for washing of fresh produce. It is highly effective at neutral pH. Chlorine dioxide is also responsible for formation hazardous by product such as chlorate and chlorite. 200 ppm of chlorine dioxide is used for sanitization of equipments while 3 ppm is used for the washing of uncut produce. Another chlorine based sanitizer acidified sodium chlorite has strong oxidizing capacity. This chemical is approved by United States Environment Protection Agency (USEPA) and United State Food and Drug Administration (USFDA).500-1200 ppm of concentration is used

DOI: http://dx.doi.org/10.5772/intechopen.107525

in dipping and spraying process on fresh fruits and vegetable, including fresh-cut. Sodium hypochlorite (NaOCl) is widely known as liquid bleach due to its bleaching property. It has various properties and globally used at household and industrial level in different concentration. NaOCl exihibits broad spectrum anti microbial activity and is used as disinfectant for various purposes. 0.5% solution of NaOCl is known as strong chlorine solution is used for areas disinfecting with body fluids. Weak chlorine solution is a 0.05% of NaOCl is used for washing hands. Study was done to compare the effectiveness of 100 mg\l of sodium hypochlorite (SH) and 500 mg\l acidified sodium chlorite (ACH) on the prevention of enzymatic browning and growth of microbial population on fresh cut produce. ACH washing reduce the microbial contamination and prevent the browning of fresh cut produce during storage. 500 mg/l ACH is effective against ant browning and anti microbial treatment of fresh cut produce [29].

5.1.2 Acid electrolyzed water

Acid electrolyzed water technique was initially developed in Japan. In this technique the diluted salt solution is passed through the containing anode and cathode separated by the membrane. Inanode side of the cell AEW is produced and results in the production of certain ions like $HOCl^-$, OCl^-, Cl_2 gas [30]. AWE is used as the disinfectant alternative to chlorine to its antimicrobial property and minimum effect on the nutritional quality of the food and health of the person. AWE provides the ensurance to the shelf life extension and safety of the fresh cut fruits and vegetables [31]. AWE act as effective technique for the inactivation of microorganism. Recently, slightly acid electrolyzed water is gaining popularity due to its less adverse effects on human health and strong bactericidal efficacy than the acid electrolyzed water [32]. Another application of AEW is NEW (neutral electrolyzed water). Function of NEW is same as AEW except that the product produced at anode is redirected to cathode and resulted into the formation of neutral solution [33]. Free Cl- and OH- ions create the high oxidation and reduction potential which result in bactericidal property [34].

5.1.3 Nanoparticles

Nanotechnology is another emerging field in science. This technique is now being used in preservation of fresh cut fruits and vegetables. In nanotechnology nanosized particles that are in the range of 1–100 nm in dimension are used to alter the physical and chemical properties of the specific material [35]. Nanopartices of various materials have been used. Silver nanoparticles has been used as antimicrobial agent in the preservation. Due this antimicrobial property these nanoparticles damage broad spectrum of microorganisms by various mechanism such as activation of antioxidant enzymes, DNA damage, depletion of antioxidant molecules, structural changes in nuclear membrane and cell wall [36]. Coating of silver nanoparticles-PVP on green asparagus leads to extended shelf life of 25 days at 2°C and 20 days at 10°C respectively [37]. Hybrid of cellulose-silver nanoparticle in combination with MAP is beneficial for the preservation of melon stored at 4°C for 10 days by retarding the senescence of melon [38]. Apart from silver nanoparticle, nanoparticles of TiO_2 and ZnO are also used in the preservation of fruits and vegetable. Nanoemulsions is one of application came under the category of nanoscience. Nanoemulsionresults in higher stability in terms of coalescence of oil droplet, gravitational separation, enhanced activity of emulsified oils, flocculation and higher surface area to droplet volume ratio

[39]. Nanoemulsions of lemongrass and oregano oil results in the reduction of microbial population to several units [9]. Likewise, an edible coating of lemongrass oil is responsible for the inactivation of *E. coli* on fresh cut apple during storage [40]. Food industries are benefitted a lot from the antimicrobial nanomaterials but safety issues to use them at commercial level are of more concern. These nanoparticles penetrate into product tissue and alter the chemical composition. Therefore, further study is required to before commercializing this technology.

5.1.4 Ozone

Fresh cut fruits and vegetables are treated with ozone in gaseous or aqueous form to extend their shelf life. Ozone came under the category of generally regarded as safe and has been approved by US FDA as direct contact food sanitizers [41]. Ozone reacts with the intracellular enzymes, nucleic acids, spore coat, components of envelop or viral capsid of microorganism. Gaseous treatment of ozone (950 μl/20 min) on sliced lettuce and spinach results in 1.0–1.5 log reduction in *E. coli* and *Listeria innocua* [42]. 9 ppm exposure of gaseous ozone results in the reduction of 2.89, 3.06 and 2.56 log in *E. coli* O_{157}, *Listeria monocytogenes, Salmonella Typhimurium*in fresh cut bell pepper. Fresh cut melon [43], apple, papaya [44] were treated with aqueous ozone (1.4 mg/5–10 min) shows significant reduction in the bacterial count while certain biochemical properties such as total phenols, PPO and POD activites, ethylene production and MDA content were reduced. Although ozone is being used in the preservation of fresh cut fruits and vegetables, special care must be given to the after effects caused by the long exposure and high concentration of it. Long exposure and increase concentration causes various health related problems so in this regard federal occupational safety and health administration in united states specified the limits on working environment (0.1 ppm for long term exposure and 0.3 ppm for short term exposure) [45]. All chemical approached for fresh cut fruits and vegetables are presented alongwith their advantages and disadvantages in **Table 1**.

Technology	Pros and Cons	Reference
Dipping in disinfectants	Use of disinfectants and sanitizers like peroxyacetic acid, chlorine, hydrogen peroxide, sodium chloride or ozone can do reduction to 1–2 log units in the initial population of the microorganism on the fresh produce.	[27]
Acid electrolyzed water	It provides the ensurance to the shelf life extension and safety of the fresh cut fruits and vegetables. Free Cl- and OH- ions create the high oxidation and reduction potential which result in bactericidal property.	[46]
Nanoparticles	The antimicrobial property these nanoparticles damage broad spectrum of microorganisms by various mechanism such as activation of antioxidant enzymes, DNA damage, depletion of antioxidant molecules, structural changes in nuclear membrane and cell wall.	[45]
Ozone	Fresh cut fruits and vegetables are treated with ozone in gaseous or aqueous form to extend their shelf life. Gaseous treatment of ozone (950 μl/20 min) on sliced lettuce and spinach results in 1.0–1.5 log reduction in *E. coli* and *Listeria innocua*.	[35]

Table 1.
Latest chemical technologies to ensure safety and to increase shelf life of the fresh cut fruits and vegetables.

5.2 Physical treatment

5.2.1 Modified atmosphere packaging

MAP is the effective technique used for the preservation and extending shelf life of the fresh cut produce. In this technique, gas composition around the product is replaced with the inert gases like CO_2, O_2 and N_2. MAP inhibits the growth of microorganisms by creating unfavorable conditions. Higher O_2 concentration is used for the preservation of aroma producing volatile substances in fresh cut honeydew melon and cantaloupe stored for 12 days at 5°C. [47] reported that the concentration of O_2 greater than 70% is proved to effective against the microbial growth and enzymatic browning in mushroom slices, shredded chicory endives and grated celeriac. The color evaluation under high O_2 concentration of these three fresh cut produce donot exceed through 6–7 days while the control sample (5% O_2 compensated with N_2) was rejected after 3–4 days. Higher O_2 concentration 50 or above 90% is effective in inhibiting the microbial growth, enzymatic browning in fresh cut lettuce stored for 6 days at 7°C [48]. [49] through research concluded that the combination of high O_2 and ascorbic acid are highly conducive to the inhibition of peroxidase and polyphenol oxidase activites and maintenance of biochemical properties of fresh cut eggplant result in extended in shelf life for 12 days at 4°C. The sample taken as control was also microbiologically accepted but the sensory score was less than the treated sample. 50% O_2 and 50% CO_2 shows the strong inhibition on the growth of yeast and the production of volatile compounds in fresh cut pineapple. This method was also reported to be responsible for the extension of shelf life. Apart from above mentioned gases, CO at low levels was also approved as GRAS as a gas used in MAP. CO is generally used in preservation of meat through MAP as it reduces the metmyoglobin and maintaining the cherry red color of meat. Very less literature is present which confirm the use of CO in fresh cut produce. [50] studied the use of CO (<175 ml/l) treatment for 20 min in fresh cut lotus root slices. This reduces the activites of PPO and POD. They also reported that the phenylalaineammonialyase (PAL) and malonaldehyde (MDA) content of treated sample were 17% lower and 40% higher than the non treated sample stored at 5°C for 8 days respectively but the controversy regarding the use of CO is still there. There are many other gases which are recently being used in MAP such as argon, helium and nitrous oxide. These noble gases indirectly affect the metabolism of the plant tissue. These gases increase the diffusivity of the O_2 from the plant tissue there by affecting certain biochemical pathways and making unfavorable conditions for the growth of microorganisms. Study was done by [51] on browning in sliced apples. N_2O and Ar (90% N_2O, 5% O_2, 5% CO_2 and 5% CO_2, 5%, 25% Ar) was used under high pressure in MAP. Results shows 15% and 25% browning in N_2O and Ar treated respectively whereas 60% in control sample stored at 5°C for 12 days. On the other hand there is increase in firmness and total soluble solid content in the treated sample. The effect of noble gases (89.3% N_2O, 89.9% Ar, 90.1% He) was compared with the air packaging in fresh cut watercress. Result shows that the C_2H_4 emission and the rate of respiration were low as compared to control but there was no effect on the growth of psychotropic and *Enterobactericeae* was observed. They suggest that the combination of other technologies with MAP to ensure the microbial safety in case of watercress [52].

5.2.2 Electron beam irradiation

Food irradiation is done for the preservation of fresh cut fruits and vegetable. Irradiation results in the negligible modification in the nutrients, taste, flavor, color and other qualities. Cobalt-60 is most frequently used radioisotope for the purpose of quality and safety of fresh produce. Lower doses of are proved to be effective in the preservation of food [46]. However these radiationshave the potential to cause cancer if used above permissible limits. EBI donot require any radioactive isotope for ionization. Electron beams are generated with the help of the machine capable of accelerating the electron close to the speed of light at high energy level in the range of 0.15–10 MeV in a vacuum environment [53]. Energy source is the commercial electricity and generator can be easily switched off and on. This technique helps to eliminate the micro flora present over the food by the destructing their DNA structure, membrane proteins and enzymes resulting in death of the organism. The effectiveness of the EBI depends the dosage of irradiation and type of food. Irradiation of blueberries with 2.3 and 3.13 kGy results in the 8.9–28 log CFU/g and 6 CFU/g decrease in the *E. coli* population. Fresh cut cabbage was treated with 2.3 and 4.0 kGy resulting in 4.0 and 7.0 log reduction in *E. coli* respectively. A research was conducted to study the correlation between the shelf life and irradiation dosage on blueberries. The result shows that the untreated blueberries decay to 39% while those treated with 2 and 3 kGy reports 8% and 3% decay respectively [38]. Mushrooms generally have shorter shelf life due to weight loss, enzymatic browning and texture changes. To overcome this mushrooms were treated with EBI at 2 kGy and then they result in the highest total antioxidant capacity, higher whiteness and lowest electrolyte leakage in mushroom. With increase in certain biochemical properties, there is decrease in vitamin C content. Despite of the successful applications discussed above, irradiation level is restricted by Food and Drug Administration (FDA) on fruits and vegetables. The maximum level at which is recommended is 1.0 kGy with the two exceptions, i.e., fresh lettuce and spinach which can be irriatedupto 4.5 kGy. Many trials of irradiation using EBI technique on fresh cut fruits is under progress, promising and encouraging results can be the hope for future research.

5.2.3 Pressurized inert gases

Inert gases such as neon, argon, nitrogen, krypton, xenon are used in the preservation of fresh cut fruits and vegetables as these gases form the ice-like crystal structure called clathrate hydrate. The gas molecules get intraped into the cage like structure by water with the help of vander Waals forces and are stable at lower temperature [54]. Various studies have been done to study the role of inert gases in the preservation of fresh cut fruits and vegetables. Shelf life of fresh cut asparagus spears was extended from 3 to 5 days to 12 days by treating them with argo (Ar), xenon (Xe) under 1.1 MPa (Ar and Xe at 2.9(v:v) in partial pressure) for 24 h at 4°C. [55] used the pressurized Argon (4 MPa) for 1 h on green peppers which results in decreased water mobility as well as loss of water, ascorbic acid growth of yeast and mold and maintaining the cell integrity by inhibiting the production of MDA and activites of POD and CAT (catalase). Use of argon on green peppers also results in the extension of shelf life to 12 days stored at 4°C as compared to the untreated ones having shelf life of 8 days. Shelf life of the fresh cut apples and pineapples can be extended from 9–7 to 15–12 days by the application of high pressure treatment of Ar at 150 MPa for 10 min and 1.8 MPa for 60 min respectively. However these treated samples possess lower scores in firmness than that of the untreated [56]. Further study was conducted by modifying this experiment by using combination of gases. Combination of argon and xenon as well as argon and nitrogen give promising results [57]. Lower growth of *Saccharomyces cerevisiae* and *E. coli* was observed in fresh cut apple and pineapple when treated with the mixture of xenone and argon under 1.8 MPa (Xe and Ar at

2:9(v:v) in partial pressure as compared to the untreated sample. On the other hand loss of ascorbic acid and total phenols, lower browning were reported under high pressure (10 MPa) nitrogen and argon on fresh cut pineapples.

5.2.4 Ultraviolent light (UV)

UV radiations are the non ionizing radiations having the wavelength in the range of 100 nm to 400 nm. These rays are classified into three different types: UV-A (315–400), UV-B (280–305), UV-C (100–280) [25]. UV-C at 254 nm is most prominently used due to its germicidal properties. UV rays causes the DNA damage in the living organism by inducing the formation of DNA photoproducts such as purimidine 6–4 pyrimidone and cyclobutane pyrimidine dimers which hinders replication and transcription and eventually leading to mutations and cell death [58]. The major advantage of UV rays is its broad spectrum action over microorganism, convenient manipulation and lower cost. Poor penetration of UV rays limits its use in food field. However, UV-C is frequently being used for the surface decontamination of fresh cut fruits and vegetables as enzymatic deterioration and surface spoilage mainly occur on surface [59]. Many studies on the use of UV on fresh cut produce gave the satisfying results. [60] reports that by treating the fresh cut apples with 1.2 kJ/m^2 UV-C lowers the microbial population to 2 log units as compared to the untreated ones stored at 6°C for 8 days. 12.5 kJ/$m^2$of UV-C shows the significant results in inhibiting PPO activity and browning in fresh cut carambola which remain fresh even after 21 days of storage. Similarly, significant results were observed in case of fresh cut apples [61]. Fresh cut peppers were treated with UV-C which eventually leads to 50% higher firmness as compared to the control sample stored at 12 day. Similarly, maintenance of antioxidant activity (DPPH activity), vitamin C content and total phenolic compounds of fresh cut paprika [62] and mandarin.

Unfortunately, due to the negative effects of UV-C on nutritional and sensory characteristic, it is in limited in use. Extended exposure of UV-C on fresh cut pineapples accelerates browning and significant decrease in Vitamin C content. High doses of UV-C causes weight loss and excess electrolyte leakage in fresh cut green onion [63]. Shelf life of watermelon is increased to 11 days at 5°C by treating it with low UV-C (1.6 and 2.8 kJ/m^2) but when treated it with high UV-C (4.8 and 702 kJ/m^2), shelf life of 8 days. Therefore the use of combination of UV-C with citric acid [64], malic acid, electrolyzed water, modified atmosphere packaging [65], gaseous ozone [66] have been developed. Recently, UV- light emitting diodes are being used due to their long life expectancy, energy efficient, low cost, convenient manipulation, no harm to human eyes and skin and no liberation of mercury waste. UVA-LED shows significant results in disinfecting food by reduction of *E. coli* on fresh cut cabbage and lettuce whilemaking no loss of vitamin C. Although, antibrowning effect is associated with irradiance, the fruit cultivar and exposure time, effective in inhibiting browning in fresh cut pear and apple [67].

5.2.5 Pulsed light (PL)

PL is thenother technique used for decontamination of packaging material and food by inactivating the microorganisms. Short duration and high power pulses are generated with inert gas (generally xenon) lamp and involve broad spectrum white light. PL results in photochemical effect and results in structural changes in DNA of viruses, bacteria and other pathogen and interferes in replication and transcription resulting mutation and eventually death of the organism. The main advantages of this technique areits low energy cost, its great flexibility, and significant reduction in very short time and lack of residual compounds. PL is recently being used for treating fresh cut fruits and vegetables. Treating fruits and vegetables with PL not only reduces the microflora, but also in the maintaience of sensory and nutritional properties of fresh cut produce. The efficiency of PL depends upon the number of pulses and intensity of the pulses. Low intensity may be ineffective while higher intensity may be toxic and cause undesirable damages. Various studies have been done on the preservation of fresh cut with the help of PL technique. Fresh cut mangoes was treated with pulsed light reports the conducive effect on the firmness, carotenoid and color of the fruit stored at 6°C for 7 days where as loss of color, firmnesswas observed in the control sample after 3 days of storage [68]. Carotenoid content oftreated sample was 9 mg/g dry matter as compared to 2 mg/g dry matter of untreated ones. Reduction in yeast and mold and maintenance of chlorophyll a and b in fresh cut avocado has been reported [69]. Exposure to high pulses (12 J/cm) results in significant reduction in *E. coli* and *Listeria innocua* in fresh cut mushroom [70]. Significant reduction was seen in *L. innocua*, *Escherichia coli, S. cerevisiae* in fresh cut apples when exposed to high pulses. However, browning action on the cut surfaces was promoted. It occurs mainly due to increase in temperature or thermal damage during the treatment which accelerates non- enzymatic and enzymatic browning. Moreover some negative effects on color, texture and sensory attributes have been reported [71]. To overcome this disadvantage combined technique was employed by [72]. PL treatment was combined with anti- browning pretreatment by dipping into mixed solution of 1%(w/v) ascorbic acid and 0.1%(w/v) calcium chloride with 71.6 J/cm^2 PL dose shows the effective results in minimizing browning on fresh cut apples. Further research must be done to find improved application of PL combine with other techniques.

5.2.6 Cold plasma (CP)

Cold plasma is anothernon-thermal technique used nowadays for the food decontamination and preservation. Plasma is defined as the fourth state of matter after solid, liquid, gas. It is the quasi neutral ionized gas which consists of photons, negative ions, free electrons, excites or non excited atoms and molecules. Various techniques are being employed for the production of plasma such as lasers, microwaves, magnetic field, electricity, direct and alternating current. Mixture of nitrogen, oxygen or mixture of other nobel gases are used in CP. Recombination process takes place between the active particles with the release of energy as visible and UV light. These active particles in the plasma react with the food substrate releasing the energy into the viruses and bacteria. Although, the exact mechanism of the inactivation is still not known but the primary mechanism of inactivation attributes to direct chemical interaction with the charged species, destruction of cellular components by UV and denaturation of DNA strand [73]. The proportion of the gas mixture and the specific energy source depend upon the chemical composition, temperature and density of the plasma. Apart from these protein, fat content, texture, pH and texture of the food also depends. This treatment is successfully applied for microbial decontamination on strawberry, potato, cherry, cabbage and milk representing significant results. [74] reported 1.76, 2.72, 0.94 log reduction of *Salmonella typhimurium* on strawberry, lettuce and potato by the use of CP technique. Another study was done on strawberries by [75] which reports 44–95% reduction of yeast and mold count and 12–85% reduction of mesophilic count. Beside this no significant change occur in color, texture and firmness of the treated product. CP treatment was given for 10,

DOI: http://dx.doi.org/10.5772/intechopen.107525

60 and 120 s to tomato resulted in 3.1, 6.3 and 6.7 log 10 CFU/sample reductions of *Salmonella, E.coli and L.monocytogenes* from the initial sample. Similar but extended treatment was given to strawberries due to its complicated surface [76] reports that 0, 15, 30, 45, 60, 90 and 120 s treatment with CP to blueberries result in the reduction of yeast/molds and total aerobic plate count to 1.5–2.0 CFU/g and 0.8–1.6 log CFU/g as compared to the controlled sample after 1 and 7 days respectively. Above mentioned studies was mainly concentrated on the fresh produce. Very few literatures is present on the application of CP on fresh cut produce due to its early stage of development. Browning area and PPO activity in fresh cut apples is reduced to 65% and 12–58% respectively by treating it with CP for 30 min compared to control after 4 h of storage. In fresh cut melon 17% POD and 7% PME activity inhibition of fresh cut melon is achieved by treating them with CP. Study done by few scientists claimed that the treatment with CP results in improved color retention and reduced browning in fresh cut kiwi fruit during storage. In addition no significant change occur in antioxidant content and antioxidant activity but slight change(up to 10%) was seen in fresh cut apples after treatment [77]. CP has gained much attention during last decade due to its promising results. However, much information about its effects on food quality and mechanism involved is unknown [78]. Further study is needed regarding physio-chemical reaction kinetics, sensorial and nutritional properties of foods. Safety issued are also not verified in case of CP. Therefore integrated risk assessment is required for its application at its commercial use.

6. Impact of different techniques on shelf life and sensory aspect

The shelf life of FCF pretreated with chemical preservatives revealed that inspite of the chemical pretreated fruits showed an increase in microbial load; yeast and mold being most prevalent over the FCF during the storage time. However, slow increase in microflora was observed over FCF pretreated with NaOCl. Antimicrobial action of NaOCl leads to reduction in pH and an increase in acidity that adds to the hurdles in the proliferation of the microorganisms during the storage period. Food processing techniques stabilize the product and lengthen their storage and shelf life, production of fresh cut fruits increases their perishability. Enzymatic browning due to oxidation of phenolic compounds lowers the product quality. Sun et al. [79] evaluated the effect of washing of fresh cut potatoes and sweet potatoes with SH and ASC. Results shows that the 500 mg/l concentration is effective alternative to SH at 100 mg/l to inhibit the browning and PPO activity hence allowing longer shelf life.

Quality of fresh cut apples was determined by dipping in organic acids and acidic electrolyzed water. Plesoianu et al. [80] conducted the to investigate the effect of citric acid (2%), benzoic acid (0.2%), sorbic acid (0.2%) and ascorbic acid (0.5%) in acid electrolyzed water. Samples were placed at 8°C for 14 days. The results indicate that the acid electrolyzed water showed less browning on fresh cut sample as compared to ascorbic acid and citric acid. The samples treated with 2% citric acid and acid electrolyzed water significantly maintained the firmness, phenol content and antioxidant activity after 14 days of storage. Nanotechnology is the advance technology for the preservation of fresh cut fruits.

A new example of this technology applied on the minimally processed fresh cut melon. Fresh cut melon (*Cucumis melo* L.) were coated with the alginate-based coating having silver nanoparticles (Ag-MMT) to study the its effect on shelf life of the product. Results shows that the treated sample was effective from microbial and sensory point of view as compared to the controlled sample hence promoting more acceptance. Prolonged shelf life was also recorded 11 days in case of treated sample as compared to 3 days in control [81]. Active packing of nano-ZnO was studied on fresh cut fuji apple by Li et al. in 2011 [82]. Cutting of fresh cut induce ethylene production which was suppressed by nanopackaging. Polyphenoloxidase and pyrogallol peroxidase acitivites were also reduced. Initial browning index was maintained 23.9 which is much lower than the control sample having 31.7 on 12th day. The research concludes that the naonpackaging could be used to increase the shelf life of the fresh cut fuji apples.

Ozone treatments were also studied for preserving the vegetable quality. Carrot color was found to be insignificantly changed after treatment at 450 ppb for 48 h, 7.6 mg l^{-1} for 15 min, and between 1 and 5 mg l^{-1} for 9.5–110.5 min. However, some dry white blotches were observed at 60 μl l^{-1} and some scattered slightly brown discolored blotches of periderm at 50 nl l^{-1} were found. Ozone behaves as postharvest stress condition that results in respiration and ethanol production due to an abnormal metabolism. An ozone supply of 15 μl l^{-1} for 8 h a day for 28 days provides some disease protection with a minimum of physical and physiological damage [83].

Modified atmospheric packaging is very common method used for the preservation of fresh cut fruits and vegetables. Study was conducted to check the effect of MAP used in combination with 2% Natureseal and evaluating the physicochemical and microbial parameters during 21 days at 4°C. Sensory quality was evaluated after 10 days of treatment. The headspace CO_2 level in MAP samples amplified significantly up to 35.3% at the end of storage; while O_2 decreased significantly. Color values were also affected with no changes in Hunter *L* and *a* values, which decreased and increased, respectively. MAP preserved the sensory eminence of fresh-cut pears up to 10 days of storage [84].

Effect of electric beam irradiation was studied on shelf life of summer truffles (tuber aestivum) packed under modified packaging. Effect of two doses of electron beam irradiation (1.5 and 2.5 kGy) on microbial population and sensory characteristics. Samples were analyzed weekly for 42 days stored at 4°C. Results showed the sample treated with 2.5 kGy e-beam has prolonged the shelf life to 42 days as compared to 21 days for the control samples [85].

Shelf life of the fresh-cut green peppers was extended using pressurized argon treatment. Fresh-cut green peppers were treated with pressurized (2–6 MPa) argon for 1 h. Control and argon-treated samples were placed in polystyrene packaging with 5% O_2 and 8% CO_2 and then stored at 4°C and 90% RH for 12 days. A range of quality parameters like chlorophyll content, Water loss, Water mobility, sensory quality, ascorbic acid loss, malondialdehyde (MDA), cell membrane permeability, cell protective enzyme activity and microbial quality were determined after every 2 days. Loss of water and water mobility was greatly reduced by the pressurized argon treatment in fresh-cut green peppers. Likewise, ascorbic acid loss, chlorophyll content and hue angle were also reduced during storage. The pressurized argon treatments were found to retain the cell integrity by inhibiting an increase in MDA and membrane permeability compared to the control samples. The treatment also reduced proliferation of coliforms, yeasts and molds. The fresh-cut pressurized argon treated green peppers can be kept in a fresh-like condition for 12 d at 4°C [47].

Latest technologies like pulsed light and cold plasma discussed in this chapter are of great importance for the preservation of fresh cut. Various researches and papers are published which shows their efficacy. Research was conducted to record fresh-cut 'Golden Delicious' apples' quality attributes after treatment with pulsed light treatment (12 J/cm^2) and a gellan-gum based (0.5% w/v) edible apple fiber enriched coating. Various physicochemical and sensory aspects were analyzed during 14 days storage at 4°C. The combined application of coating and PL treatment retarded the microbiological deterioration of fresh-cut apples and maintained the sensory attribute scores above the rejection limits after prolonged storage [86]. Same technique was applied to maintain the physicochemical and nutritional profile of fresh cut mangoes. Pulsed light treatments were carried out using an automatic flash lamp system (Mulieribus, Claranor) composed of eight lamps situated all around the sample with a total fluence of 8 J^{cm-2}. Pulsed light treatment maintained the firmness, color and the carotenoids of fresh-cut mangoes.

Cold plasma technique is used for the preservation of minimally processed products. Misra et al. [87] reported the control and CP treated tomatoes showed decrease in respiration rate during the storage. However, the respiration rates were similar for the control and CP-treated tomatoes at the end of storage. The results of Tappi et al. [88] showed that the plasma treatment can cause an alteration of the cellular respiratory pathway. Misra et al. [89] utilized cold plasma treatment for strawberries in modified atmosphere packaging that revealed no significant increase in respiration rate. Tappi et al. [88] reported that cold plasma treatments results in an increase of firmness in fresh-cut apples. The amount of firmness was 18.9 N for the control and 21.8 N for plasma-treated samples at 15 kV for 10 min. The highest firmness was found in cold plasma treated mushrooms which indicates the impending application of this inventive technology in escalating the shelf-life and quality of mushroom after harvesting [90].

7. Future trend in processing of fresh cut fruits and vegetables

In last few years there is revolution in fresh cut industry. Stepping of women into the jobs cause radical change in the lifestyle and very less time is left for the preparation of meal for the whole family. Industrial kitchen have to prepare food for large number of people with limited number of labour. Moreover, consumers are becoming more health conscious as a result there is change in their food choices and prefer fresh and convenient product. This scenario created a challenges as well as opportunity for products into the market like fresh cut fruits and vegetables as a way to increase consumption of vegetables and fruits. Fresh cut product results in greater demand among the consumer for quality appearance, convenience and healthy nutrition. Various fresh cut products are already present in the market boosting and attracting consumers. Minimally processed food occupy special place in the market and is one of the major growing segment in the food industry. Being organic, these products stand out from rest of the products. Fresh cut salads mixes are fastest growing categories growing at the rate of 200% over the past 3 years.

Due to the raw materials diversity, processing conditions and packaging systems used in the production of fresh-cut products, it is impossible to institute a one-size fits-all approach to attain microbial safety. Rather, the producer has to vigilantly consider an extensive variety of factors and hurdles—quality of raw material, hygienic conditions, storage temperature, water content, acidity, modified atmosphere conditions—in formative ways to control microbial growth. Through the potential selection and combination of these factors, the producer is able to concluding the optimum shelf life of the product and ensures safe products for end consumers. Hence, safety and sanitation are the top priority parameters for fresh-cut processors. New design essentials of processing equipment are a critical part of this uninterrupted evolution of food safety and sanitation. These elements aid the plant managers to implement cleaning practices more effectively.

The high influence placed on hygienic design of fresh-cut processing facility and equipments is a new trend now days. Since microorganisms are ever-present and mutate incessantly by adapting to different types of disinfectants and sanitizers, it is extremely important to develop vibrant sanitary protocols to control microbial contamination efficiently. To all stakeholders in the fresh-cuts industry (from regulators to processors to equipment manufacturers), equipment designed with hygienic goals in mind is fast becoming an area of primary concern. For this reason, sanitation design and protocols will continue to develop that organizations need to apply collective knowledge and advanced engineering to create safer and more proficient processes. Organizations such as UFPA (United Fresh Produce Association), PMA (Produce Marketing Association) and the USDA offer plant owners and managers information on what to look for in processing equipment that will best suit their needs within a plant. These organizations also offer important guidance to manufacturers to continually grow and develop their easy-to-clean designs. Maximizing use of the knowledge base is the best way to maintain the advance in safety and sanitation process in the fresh-cut industry. Additionally, the industry and its organizations are operational with equipment manufacturers to establish sanitary equipment design guidance in a proactive effort to offer basic flowcharts, and checklists to help in the evaluation of effective sanitary design attributes. The FDA, moreover, is focusing on the cleanability of processing equipment during strengthened inspections of food processing facilities.

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