International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(3): 2230-2235

Received: 07-03-2018
Accepted: 09-04-2018

Owais Yousuf
Research Scholar, Department of Post-Harvest Process & Food Engineering, College of Technology, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Iftikhar Alam
Research Scholar, Department of Post-Harvest Process & Food Engineering, College of Technology, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Mohd Ishfaq Bhat
Research Scholar, Department of Post-Harvest Process & Food Engineering, College of Technology, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Sushree Titikshya
Research Scholar, Centre of Rural Development and Technology, Indian Institute of Technology Delhi, Hauz Khas, New Delhi, India

Correspondence
Owais Yousuf
Research Scholar, Department of Post-Harvest Process & Food Engineering, College of Technology, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Assessment of microbial spoilage and techniques to avert the deterioration in fruits and vegetables

Owais Yousuf, Iftikhar Alam, Mohd Ishfaq Bhat and Sushree Titikshya

Abstract
Consumption of vegetable and fruit commodities has intensely augmented about 30% in each part of the world throughout past decades, but its wastage was also assessed around 20 % of all vegetables and fruits produced each year. Simultaneously, customer need for accessibility commodity is growing and so is the demand for fresh-cut vegetables and fruit. Yet the standard and safety of such commodity is the subject of matter as they are more vulnerable to deterioration and can enable quick development of putrefactive micro-organisms. Spoilage may rise from insect damage, indigenous enzyme activity and physical damage in the plant tissue or by microbial contaminations. The emphasis of this discussion is to deliver a general overview of the damages and distinctive microbial spoilage of vegetable and fruits and also some of the innovative techniques to avert the deterioration and prolong the shelf life.

Keywords: Microbiology, spoilage, vegetables and fruits, microorganisms, shelf-life

Introduction
Fruits and vegetables consumption has considerably augmented in the past decade. In fact they have now become an essential part of our daily diet. This change can be ascribed to increased awareness in healthy eating habits. It has been found that the vegetables and fruits are the rich in dietary fibers and their consumption can be very beneficial in counteracting several chronic diseases like cardiovascular diseases and cancers. These factors have led to the increased productivity of vegetables and fruits. But maximum of the efforts are being concentrated to the production, not to post harvest operations. This is why most of fruits and vegetables produced are rejected every year because of spoilage (Barth *et al*., 2009) [5].
Spoilage in case of foods can be describes as the changes which the consumer finds to be unacceptable. It leads to variations in the sensory attributes of the vegetables and fruits and makes them undesirable for the consumption. Spoilage does not occur specifically at a certain place in the food chain. In fact it might take place at any stage along the whole food chain. The various spoilage causing agents include physical damage, insect damage, enzyme activity or by microbial infections. Most vegetables and fruits have an inadequate life and are more vulnerable to spoilage. It is found that enzymes are responsible for degradation in some vegetables and fruits while chemical reactions such as rancidity and oxidation destroy others. But the most destructive cause of spoilage among all is by microorganisms such as bacteria, moulds and yeast (Jay, 1992) [16].

Fruits and Vegetables Losses
Overall worldwide vegetables and fruit losses come around 30 to 40% annually (Barth *et al*., 2009) [5]. In several countries the condition is worse and the losses are even higher. It is thus obvious to decrease losses so as to guarantee that the sufficient produce, both in quantity and in quality is available to every person. Reduction of the losses of vegetables and fruits leads to various positive outcomes. It leads to the reduction in the production cost, trade and distribution. These things in turn help in lowering the value for the customer and an increment in the farmer's income. Fruits and vegetables are very important food produces not solitary in India but in the whole world. India is the fourth largest producer of fruits and second main producer of vegetables in the world (Rawat, 2015) [25]. Although India is producing sufficient amounts of vegetables and fruits but due to the damages in the field in addition to in storage, they become insufficient.

About 30% fruits and vegetables are not suitable for ingesting because of damage after harvesting (Qadri *et al*., 2015) [23]. Fruits and vegetables are perishable and extremely susceptible to losses because they are made up of living tissues. Required measures should be taken to keep these tissues alive and healthy throughout the supply chain. Fruits and vegetables are mostly prone to microbial decomposition initiated by moulds, bacteria, fungi and yeast. Among them a significant portion is lost during post-harvest period which is attributed to diseases caused by bacteria and fungi. Not only fresh fruits and vegetables, these organisms are also capable of damaging processed and canned products.

Fruits and Vegetables Spoilage

The key cause of microorganisms in vegetables and fruits are soil, water, air, and other environmental factors. Most vegetables are rich in carbohydrates, low in proteins, and have high pH (Sapers *et al*., 2005) [28]. The presence of higher temperature, high humidity and air throughout storage adds on the probabilities of spoilage. The common deterioration flaws are triggered by molds fitting to genera Alternaria, Botrytis, Penicillium, Phytophthora, and Aspergillus and among the bacterial genera, species from Pseudomonas, Clostridium and Bacillus are vital (ref). Microbial vegetable deterioration is commonly defined by the term rot. This rot can be of numerous kinds subject to the variations in the appearance. The best common rots are soft rot, black rot, stem-end rot, pink rot and gray rot (Hozbor *et al*, 2006) [12].

Vegetables are common source of nutrients for spoilage organisms because of their near neutral pH and high water activity. Bacteria and molds are benefitted from the chilling and mechanical deterioration to the plant surface which occurs during storage where losses due to microorganisms are comparatively less. Certain microbes are found in solitary limited kinds of vegetables whereas others are widespread. *Erwinia carotovora* is the furthermost spoilage bacterium and has been spotted in almost all kind of vegetable. It can even develop at refrigeration temperatures (Tournas, 2005) [30].

Bacterial deterioration initially softens the tissues as pectin is degraded and the entire vegetable may ultimately spoiled into a slimy mass. Sugars and Starches breaks down next and nasty odors and flavors progress along with ethanol and lactic acid. Besides E. carotovora, numerous Pseudomonas spp. and lactic acid bacteria are significant spoilage bacteria (Jay, 1992) [16]. Molds fitting to various genera, including Rhizopus, Alternaria and Botrytis, initiates number of vegetable rots which can be predicted by their texture, color or acidity (Nguyen-the and Carlin, 1994) [20]. Healthy fruits have microbes on their surfaces but can usually constrain their growth until after harvest Ripening leads to the weakening of the cell walls which in turn reduces the quantity of antifungal chemicals present in fruits. At the same time physical damage by harvesting cause additional rupture in the outer protective layers of fruits that act as the active sites for the deterioration organisms to exploit. Molds are more tolerant in low water activity and acidic conditions and are thus connected in deterioration of citrus fruits, pears, apples and other fruits (Abadias *et al*., 2008) [2].

Table 1: General Types of Microbial Spoilage (Qadri *et al*., 2015) [23].

S. No	Spoilage	*Cause*	Effect
1	Bacterial soft rot	*Erwinia carotovora*	water soaked appearance soft mushy consistency often a bad odor
2	Gray mold rot	*Botrytis cinerea*	favored by high humidity and a warm temperature Grapes
3	Rhizopus soft rot	*Rhizopus stolonifer*	often soft and mushy cottony growth of the mold small black dots of sporangia often covers the food Sweet potatoes, tomatoes
4	Anthracnose	*Collectotrichum lindemuthianum*	defect is spotting of leaves and fruits or seed pods Beans
5	Alternaria Rot	*Alternaria tenuis*	greenish brown early in the growth of the mold later turn to brown or black spots Citrus Fruits
6	Blue mold rot	*Penicillium digitatum*	Bluish green color spores are produced Citrus Fruits
7	Downey mildew	*Phytophthora, Bremia*	molds grow in white, woolly masses Grapes
8	Watery soft rot	*Sclerotinia sclerotiorum*	Found mostly in vegetables Carrots
9	Stem end rots	*Diplodia, Alternaria, Phomopsis, Fusarium*	Involve the stem end of fruits Citrus Fruits
10	Black mold rot	*Aspergillus niger*	Dark brown to black masses of spores of the mold termed “Smut” by layperson. Onions
11	Black rot	*Alternaria, Ceratostomella, Physalospora*	Sweet potatoes
12	Pink mold rot	*Trichothecium roseum*	
13	Fusarium rots	*Fusarium*	Potatoes
14	Green mold rot	*Cladosporium*	Cherries, Peaches
15	Brown rot	*Sclerotinia fructicola*	Peaches, Cherries

Prevention methods of Fruits and Vegetables from Spoilage Microorganisms

Fruits and vegetables are delicate by nature, thus need guard from deterioration throughout their processing, storage and distribution to provide them preferred shelf-life. Microbes require certain conditions for growth. Therefore management of the environment of vegetables and fruits can change these factors and delay spoilage. Vegetables and fruits are collected into boxes, baskets, trucks during harvesting. They might get contaminated by spoilage causing organisms from each other or from the containers unless these have been adequately sanitized. Mechanical damage while transportation from field to market may upsurge vulnerability to deterioration as development of microorganism take place (Ragaert *et al*., 2007) [24]. Pre-cooling of the commodity and refrigeration during transportation will slow such growth. Soaking, washing through agitation tends to restrict spoilage causing organisms from damaged to complete foods. Recirculate or recycled water is probable to enhance organisms and the washing process might moisten surfaces enough to license development of organisms throughout the holding period. Washing with the help of detergent and numerous other antimicrobial solutions will decrease the numbers of microbes from the surface of fruits and vegetables. Different microorganisms have their own growth conditions. Several microbes propagate slowly or not at all at low temperatures, and refrigeration can lengthen the lag phase and decline development rate of microbes (Buck *et al*., 2003) [7]. Some microbes need oxygen for their survival while in case of others oxygen is the source for their destruction, and even others are facultative. Handling the atmosphere throughout storage in packaging can delay or avert the development of some microbes. In order to avert vegetables and fruits from microbial deterioration and to improve their shelf life, certain finest possible techniques are as follows:

1. Asepsis: Vegetables and fruits may get contaminated between the stages of harvesting and processing due to already spoiled produce or from the containers carrying the produce. Boxes, baskets and other containers ought to be practically free of the existence of microorganisms and in this case they should be properly cleaned and sanitized (Gram *et al*., 2002) [11]. Thus proper precautions need to be taken so as to avoid the contagion of vegetables and fruits during harvesting, transporting and processing.

2. Washing Treatment: Washing of vegetables and fruits removes the maximum of the spoilage causing microorganisms, dirt and other surface contaminants. The water which is used for the washing purpose must be of appropriate microbial standard to avert the contamination. Recirculate water should have sufficient quantities of an approved wash water disinfectant to decrease the probabilities of cross contamination of all the produce in washing. Chlorinated water is mostly used for washing. Part of the mold development on strawberries can be removed by washing with a nonionic detergent solution (Parish *et al*., 2003) [22]. Washing – Removes dirt, microorganisms and toxic sprays. Washing may be with detergent solutions, water and bactericidal solutions such as chlorinated water. Trimming of vegetables and fruits also clues to the removal of microorganisms.

3. Thermal Treatment: Heat treatment or thermal treatment is considered as the oldest, common and effective ways to prevent spoilage in fruits and vegetables. The high temperatures ensure that microorganisms are killed and the enzymes are inactivated. Yet it is vital to recall that certain micro-organisms are unfortunately less subtle to heat: *Staphylococcus* and *Clostridium* can still increase and damage the food through the toxic matters they produce (Jacxsens *et al*., 2001) [14]. *Clostridium* can cause botulism and which can lead to severe diseases. This bacterium does not survive in more acidic conditions and products such as fruits whose pH is less than 4.5 (Lund *et al*., 2000) [18]. The heating method for fruits is different than for most vegetables as fruits have a low pH level. Fruits can be heated in boiling water (100°C), whereas most vegetables have to be heated at temperatures above 100°C, because they have a higher pH and are thus more susceptible to bacterial contamination (Raybaudi-Massilia *et al*., 2009) [26]. Maximum microorganisms are destroyed by thermal treatment thus leading to less probabilities of spoilage.

4. Low Temperature Storage: Low temperature storage is the most common type of storage for vegetables and fruits. It is also called cellar storage. This kind of storage is operative in event of those vegetables and fruits which have minor probabilities of deterioration under these situations and can last long without any further processing. The various vegetables and fruits which are relatively steady under low temperature conditions include apples, root crops, cabbage, potatoes (Francis *et al*., 2012) [9]. Placing warm produce with field heat into a cold room with insufficient refrigeration capacity will cause a temperature upsurge in the room and, as the room cools, a mist or fog might occur. As the water condenses out of the air and onto surfaces of walls and ceilings that harbor human pathogens, contaminated condensate may end up dripping onto the stored produce. Thus, it is vital that sufficient cooling capacity is available when cooling produce. Also the optimal storage temperature differ for varies kind of vegetables and fruit. Therefore the storage temperature should be accustomed accordingly to avoid any chances of chilling injury.

5. Hydrocooling: Hydrocooling is an intermediary process of cooling the vegetables and fruits, before normal cold storage, directly after harvesting by the use of a cold water spray. This is mostly done so as to eliminate the field heat, maintain the freshness and for the elimination of spoilage causing microorganisms. It is particularly important that water used for Hydrocooling of vegetables and fruits be free of pathogenic microorganisms, as when warm produce is placed in cold water, intercellular air spaces within vegetables and fruits contract, creating a partial vacuum (pressure differential). This has been confirmed to facilitate infiltration of water, which might comprise of human pathogens, into fresh produce item (Allende *et al*., 2008) [4].

6. Chilling Storage: Vegetables and fruits have their own optimal conditions for chilling storage which include relative humidity and temperature. These conditions vary from product to product and even the optimal conditions may vary for the different diversities of the same product. The fresh produce to be stored under chilling conditions is treated primarily with various chemicals which include hypochlorites, sodium bicarbonate, borax, propionates, biphenyl, o-phenylphenols, sulfur dioxide, thiourea, thiabendazole, dibromotetrachloroethane (Issa-Zacharia *et al*., 2010) [13]. In case of some fruits, they are enclosed in wrappers treated with chemicals like Sulfite paper on grapes, iodine paper on grapes and tomatoes, borax paper on oranges. Waxed wraps, paraffin oil, paraffin, waxes and mineral oil is also applied for mechanical protection. Vegetables are air-conditioned quickly without any special processing and stored at chilling temperatures for avoiding the spoilage. Chilling of the vegetables and fruits is accomplished mostly using ice, cold water, mechanical refrigeration or by vacuum cooling.

7. Freezing: Freezing is an effective technique for saving the vegetables and fruits from getting damage and also for the preservation of products. While preparation of fruits for freezing, unwanted variations might occur like darkening of the produce, flavor deterioration and decomposition by microorganisms especially molds (Abadias *et al*., 2006) [1]. In this case cleaning the fruit eradicates most of the soil microorganisms and better sorting and trimming will reduce most of the molds and yeasts which are the common spoilage causing agents (Tournas, 2005) [30]. Thus proper preliminary processing may definitely aid in the long lasting spoilage free produce during freezing. Yeasts like *Saccharomyces*, *Cryptococcus*, molds like *Fusarium*, *Aspergillus*, *Rhizopus*, *Penicillium*, *Botrytis*, *Alternaria and Mucor* are the major organisms in frozen fruits. Yeasts mostly grow during slow thawing (Gorny, 2006) [10]. Numbers of feasible microorganisms in frozen fruits are considerably lower than in frozen vegetables. In case of vegetables freezing process decreases the quantity of microorganisms on an average to about half of the originally present. *Micrococcus* is predominant on thawing vegetables such as sweet corn and peas (Barth *et al*., 2009) [5]. *Achromobacte*r and *Enterobacter* are also commonly present (Cotter *et al*., 2005) [8]. *Lactobacillus* is also common on peas under such conditions (Gorny, 2006) [10]. One species of *Micrococcus* may grow at first followed by another species later. At higher temperatures, species of *Flavobacterium* also may multiply. During freezing most vegetables wilt and become limp and during storage frozen vegetables may undergo color changes. When thawed vegetables are held at room temperature for any considerable period, there is a chance that spoilage causing bacteria may grow and produce toxin.

8. Drying: Drying is among the oldest knowing preservation methods for vegetables and fruits. The moisture content of the fresh produce is decreased to 10-15% so that the existing microorganisms cannot flourish and the enzymes become sedentary (Rico *et al*., 2007) [27]. With the aim of making sure that the produce do not pamper after being dried, they have to be kept in a moisture-free environment. Drying is generally not difficult. Since the products lose water, they also become much lighter and thus easier to transport. Two disadvantages, however, are that the products also lose vitamins, and they change in appearance. Before drying, the vegetables and fruits have to be washed thoroughly and cut into pieces if necessary. Sometimes extra preparation is needed to retain the product’s colour and to curtail the nutrient loss. Quantity of microorganisms in dried fruits is comparatively low and that spores of molds and bacteria count are many (Raybaudi-Massilia *et al*., 2009) [26]. Before drying, pretreatments of alkali, sulfuring, blanching and pasteurization reduce the quantity of microorganisms in fruits. Dried vegetables and vegetable commodities are used in dried soups. Dried spices and condiments are used as flavoring materials. Drying by heat destroys yeasts and maximum bacteria, but spores of molds and bacteria generally endure.

9. Explosive puffing: It is a type of drying used specifically for certain vegetables. In this method small, diced pieces of partly dehydrated vegetables are taken and placed for further processing in a sealed rotating chamber. Heat is supplied and the chamber is pressurized to a pre-determined level, then the pressure is freed instantaneously. It consequence to additional loss of water, but more important, a porous network of capillaries is formed in the product. The augmented porosity shortens further drying and imports better re-forming skill (Jinfeng and Yimin, 2008) [17].

10. Packaging: Packaging functions as the most effective part in the storage and transportation of fruits and vegetables. As it is obvious that packaging materials come in direct contact with fresh fruits and vegetables thus they may serve as a source of contamination. Packaging materials which include boxes and plastic bags require storage in such a method as to defend them from insects, rodents, dust, dirt, and other potential sources of infection which include microorganisms as well (Buck *et al*., 2003) [7]. All packaging materials cannot be stored inside enclosed facilities due to space constraints. However, if packaging materials are stored outside an enclosed building, sufficient precautions are to be taken to reduce the probability of microbial infestation, and measures should be taken to allow for effortlessly recognizable indicators of an infestation. Plastic field bins are favored to wooden containers, since plastic surfaces are more exposed to sanitizing and cleaning, which should be done after each use to diminish the potential for cross contamination. Cardboard field bins if reused must be visually checked for cleanliness and lined with a polymeric plastic bag before reuse to avert the possible danger of cross contamination (Sapers *et al*., 2005) [28].

11. Controlled Atmosphere (CA) Storage: Controlled atmosphere storage is considered as finest possible technique of storage for avoiding spoilage and preservation of vegetables and fruits. Fruits are mostly stored using this technique in comparison to vegetables. This storage is based on the alteration of various gases from normal atmospheric concentrations. This is usually achieved by increasing the concentration of carbon dioxide and decreasing the concentration oxygen in the storage system. Optimal concentrations of oxygen and carbon dioxide differ with the type and variety of fruits. The most common fruits stored under CA storage include apples, pears, bananas, plums, peaches, grapes, citrus fruits. Ozone in concentrations of 2 to 3 ppm in the atmospheres doubles the storage time of loosely packed small fresh fruits, such as straw berries, raspberries, currants and grapes and delicate varieties of apples (Sivertsvik *et al*., 2002) [29]. Ethylene in the atmosphere is used to accelerate ripening or produce a desired color change and it is not considered preservative, although a combination of this gas and activated hydrocarbons can be utilized (Jacxsens *et al*,. 2003) [15].

12. Chemical Preservatives: With the intention of avoiding the spoilage and increase the shelf life of vegetables and fruits, chemical preservatives may also be applied as a vital and effective treatment. Chemical preservatives are added to the produce just to delay, constrain or seize the action of microorganisms such as fermentation decomposition and putrefaction of the commodity. Commonly used preservatives include, spices, sugar, dextrose, vinegar, common salt, ascorbic acid, lactic acid and its salts, benzoic acid and its salt, nitrates, sorbic acid and its salts, Sulphur dioxide and the salts of sulphuric acid, propionic acid and its salts (Bhagwat *et al*., 2004) [6]. Chemicals are applied to the fruits primarily as dips or spray or saturated in wrappers. Various chemical substances applied to the surfaces of fruits are hypochlorites, waxes, alkaline sodium o-phenylphenate and biphenyl (Issa-Zacharia *et al*., 2010) [13]. Wrappers for fruits have impregnated with a variety of chemicals include iodine, sulfite, biphenyl, o-phenylphenol plus hexamine and others (Oms-Oliu *et al*., 2010) [21]. Gaseous preservatives include carbon dioxide, ozone and ethylene plus chlorinated hydrocarbons. Sulfur dioxide and sodium benzoate are the most common preservatives that have been added directly to fruits or fruit products. Addition of preservatives is not that common in vegetables as in fruits barring a few. Rutabagas and turnips sometimes are paraffined to increase their shelf life. Zinc carbonate has been found to remove most mold growth on beets, and spinach and lettuce (Allende *et al*., 2004) [3].

13. Preservation by irradiation: Irradiation is one of the advanced techniques used specifically for making the surface of vegetables and fruits free from spoilage causing microorganisms. Gamma rays are used to inactivate the microorganisms causing spoilage. Irradiation is used successfully to delay spouting of potatoes, onions and garlic and to kill insect reproduction on some vegetables (Molins *et al*., 2001) [19]. However this technique cannot be applied to all vegetables and fruits.

14. Refrigerated Transport and Distribution: Produce is best shipped in temperature-controlled refrigerated vehicles. Maintaining perishables at their appropriate temperature when being transported to destined markets helps in prolonging the shelf life. When appropriate, holding fresh vegetables and fruits at low temperature considerably decrease the development of microbes including spoilage causing microbes (Hozbor *et al*., 2006) [12]. Trucks used during transportation are also a potential source of contamination from spoilage causing microorganisms. Therefore, trucks are routinely washed and sanitized on a regular basis, and trucks that have been utilized to transport live animals, animal products, or toxic materials are not used to transport produce or used only after effectual washing and sanitation.

Conclusion
Consumer concern for safety and standard of delicate commodity is rising despite of its consumption has augmented. The utmost prerequisite is the identification of the detailed deteriorative microorganisms for diverse kinds of fresh-cut commodity stored under exclusive packaging situations. Owing to the rising awareness, there is also a necessity for research of spoilage arrays and micro flora of vegetables and fruits commodity packaged with novel, evolving MAP techniques, as well as, technologies to processors so as to safeguard safety while preserving the sensory and nutritional properties. Thus, utmost care has to be taken to recover and preserve microbiological standard of vegetables and fruits produce during its preparation and till its ultimate consumption. Temperature is utmost influential features disturbing the standard and microbiological attributes of commodity, thus, further investigate is needed to influence cold chain on microbial flora and shelf life of both whole and fresh-cut produce, particularly fresh-cut fruits.

Acknowledgement
We are highly grateful to our fellow researchers and faculty members for their support and appreciation from the Department of Post-Harvest Process and Food engineering, GBPUAT, Pantnagar, India

References
1. Abadias M, Canamas TP, Asensio A, Anguera M, Vinas I. Microbial quality of commercial ‘golden delicious’ apples throughout production and shelf-life in Lleida (Catalonia, Spain). International Journal of Food Microbiology. 2006; 108:404-409.
2. Abadias M, Usall J, Anguera M, Solsona C, Viñas I. Microbiological quality of fresh, minimally-processed fruit and vegetables, and sprouts from retail establishments. International journal of food microbiology. 2008; 123(1-2):121-129.
3. Allende A, Aguayo E, Artés F. Microbial and sensory quality of commercial fresh processed red lettuce throughout the production chain and shelf life. International Journal of Food Microbiology. 2004; 91:109-117.
4. Allende A, Selma MV, López-Gálvez F, Villaescusa R, Gil MI. Role of commercial sanitizers and washing systems on epiphytic microorganisms and sensory quality of fresh-cut escarole and lettuce. Postharvest Biology and Technology. 2008; 49:155-163.
5. Barth M, Hankinson TR, Zhuang H, Breidt F. Microbiological spoilage of fruits and vegetables. In Compendium of the microbiological spoilage of foods and beverages. Springer, New York, NY, 2009, 135-183.
6. Bhagwat AA, Saftner RA, Abbott JA. Evaluation of wash treatments for survival of foodborne pathogens and maintenance of quality characteristics of fresh-cut apple slices. Food Microbiology, 2004; 21:319-326.
7. Buck JW, Walcott RR, Beuchat LR. Recent trends in microbiological safety of fruits and vegetables. Plant health progress. 2003; 10(1):1094.
8. Cotter PD, Hill C, Ross RP. Food microbiology: bacteriocins: developing innate immunity for food. Nature Reviews Microbiology. 2005; 3(10):777.
9. Francis GA, Gallone A, Nychas GJ, Sofos JN, Colelli G, Amodio ML *et al*. Factors affecting quality and safety of fresh-cut produce. Critical Reviews in Food Science and Nutrition. 2012; 52:595-610.
10. Gorny J. Microbial contamination of fresh fruits and vegetables. Microbiology of fruits and vegetables. CRC Press, Boca Raton, FL, 2006, 3-32.
11. Gram L, Ravn L, Rasch M, Bruhn JB, Christensen AB, Givskov M. Food spoilage-interactions between food spoilage bacteria. International journal of food microbiology. 2002; 78(1-2):79-97.
12. Hozbor MC, Saiz AI, Yeannes MI, Fritz R. Microbiological changes and its correlation with quality indices during aerobic iced storage of sea salmon (*Pseudopercis semifasciata*). LWT-Food Science and Technology. 2006; 39(2):99-104.
13. Issa-Zacharia A, Kamitani Y, Muhimbula HS, Ndabikunze BK. A review of microbiological safety of fruits and vegetables and the introduction of electrolyzed water as an alternative to sodium hypochlorite solution, 2010.
14. Jacxsens L, Devlieghere F, Ragaert P, Van der Steen C, Debevere J. Effect of high oxygen modified atmosphere packaging on microbial growth and sensorial qualities of freshcut produce. International Journal of Food Microbiology. 2001; 71:197-210.
15. Jacxsens L, Devlieghere F, Ragaert P, Vanneste E, Debevere J. Relation between microbiological quality, metabolite production and sensory quality of equilibrium modified atmosphere packaged fresh-cut produce. International Journal of Food Science and Technology. 2003; 31:359-366.

16. Jay JM. Bioassay and Related Methods. In Modern food microbiology. Springer Netherlands, 1992, 166-184.
17. Jinfeng B, Yimin W. Review on explosion puffing drying for fruits and vegetables at variable temperature and pressure difference. Transactions of the Chinese Society of Agricultural Engineering, 2008, (6).
18. Lund B, Baird-Parker TC, Gould GW. (Eds.). Microbiological safety and quality of food. Springer Science & Business Media, 2000, 1.
19. Molins RA, Motarjemi Y, Käferstein FK. Irradiation: a critical control point in ensuring the microbiological safety of raw foods. Food control. 2001; 12(6):347-356.
20. Nguyen-the C, Carlin F. The microbiology of minimally processed fresh fruits and vegetables. Critical Reviews in Food Science & Nutrition, 1994; 34(4):371-401.
21. Oms-Oliu G, Rojas-Graü M, González LA, Varela P, Soliva-Fortuny R, Hernando MH *et al*. Recent approaches using chemical treatments to preserve quality of fresh-cut fruit: A review. Postharvest Biology and Technology. 2010; 57:139-148.
22. Parish ME, Beuchat LR, Suslow TV, Harris LJ, Garrett EH, Farber JN *et al*. Methods to reduce/eliminate pathogens from fresh cut produce. Comprehensive Review Food Science Food Safety. 2003; 2:16-173.
23. Qadri OS, Yousuf B, Srivastava AK. Fresh-cut fruits and vegetables: Critical factors influencing microbiology and novel approaches to prevent microbial risks-A review. Cogent Food & Agriculture, 2015; 1(1):1121606.
24. Ragaert P, Devlieghere F, Debevere J. Role of microbiological and physiological spoilage mechanisms during storage of minimally processed vegetables. Postharvest Biology and Technology, 2007; 44(3):185-194.
25. Rawat S. Food Spoilage: Microorganisms and their prevention. Asian Journal of Plant Science and Research. 2015; 5(4):47-56.
26. Raybaudi-Massilia RM, Mosqueda-Melgar J, Soliva-Fortuny R, Martín-Belloso O. Control of pathogenic and spoilage microorganisms in fresh-cut fruits and fruit juices by traditional and alternative natural antimicrobials. Comprehensive reviews in food science and food safety, 2009; 8(3):157-180.
27. Rico D, Martin-Diana AB, Barat JM, Barry-Ryan C. Extending and measuring the quality of fresh-cut fruit and vegetables: a review. Trends in Food Science & Technology. 2007; 18(7):373-386.
28. Sapers GM, Gorny JR, Yousef AE. (Eds.). Microbiology of fruits and vegetables. CRC Press, 2005.
29. Sivertsvik M, Jeksrud WK, Rosnes JT. A review of modified atmosphere packaging of fish and fishery products-significance of microbial growth, activities and safety. International Journal of Food Science & Technology. 2002; 37(2):107-127.
30. Tournas VH. Moulds and yeasts in fresh and minimally processed vegetables, and sprouts. International journal of food microbiology. 2005; 99(1):71-77.