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REVIEW ARTICLE

Application of hurdles for extending the shelf life of fresh fruits

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Abstract

Fruits, when harvested have high moisture content and higher water activity that provides suitable ground for the growth of microorganisms. In addition, the biochemical and metabolic processes do not cease; though the fruit have left their parent plants. The processes such as respiration, senescence, and conversion of starch etc. contribute to the degradation process. Therefore, preservation of these fresh fruits becomes the top most priority for the producers, dealers and vendors. More than 100 methods are followed worldwide for preservation of different kinds and forms of foods. Most of these technologies aim at controlling the microbial growth for food safety, simultaneously altering the composition, colour, and taste of the produce. The likeness and public awareness for consumption of minimally processed or fresh like food has brought the concept of hurdle technology. The technology initially applied to meat preservation, has evolved into preservation of minimally processed foods, processed foods etc. This involves combination of two or more methods that act synergistically, like application of chlorine, ozone, chemical, ultrasound, hyperbaric pressure, active packaging/MAP, edible coating, electromagnetic waves in moderate doses and storage at suboptimal temperature and humidity, causing least damage to the quality parameters, thereby extending the shelf life of fresh fruits.

Keywords: Fruits, climacteric, non-climacteric, hurdles, temperature.

Introduction

Fruits are rich in carbohydrates, vitamins, and minerals and poor in proteins, with pH values ranging from 7.0 to slightly acidic, and exhibit a characteristic high water activity. These conditions make the produce suitable ground for growth of several bacteria, yeasts and moulds (Ramos *et al*., 2013). Fruits deteriorate rapidly after harvest and in some cases do not reach consumers at optimal quality after transport and marketing. Post harvest, the fruits are still respiring and other metabolic processes still continuing. Even mild bruising can contribute largely to the produce's deterioration through enzymatic reaction and microbial contamination. By the time the fruit reaches the consumer's gut, it goes through different phases, witnessing and sustaining different handling and storage conditions. Spoilage may be caused by a wide range of reactions such as physical, chemical, enzymatic, and microbiological. The various forms of microbiological spoilage are preventable to a large - degree by a wide range of preservation techniques, most of which act by preventing or inhibiting microbial growth (e.g., chilling, freezing, vacuum packing, modified atmosphere packing and adding preservatives). A smaller number of techniques act by inactivating microorganisms (e.g., pulse electric field, irradiation). Additional techniques restrict the access of microorganisms to products (e.g. packaging). A major trend is that new and emerging preservation techniques, which are coming into use or are under development, include more than one act of inactivation (e.g., hypobaric pressure, electroporation, manothermosonication and addition of bacteriolytic enzymes). A further trend is towards the use of procedures that deliver less heavily preserved products with higher retention of quality, more natural, free from additives, and nutritionally healthier. Less severe preservation procedures are therefore being developed that make use of preservative factors in combinations to deliver less damage to product quality (Gould, 1996).

Fruit contamination problems can occur in the growing environment. During growth the fruit can become contaminated from sources such as soil, water, animals, birds, and insects. Following production, the processes of harvesting, washing, packaging, and shipping can create additional conditions. The quality of food can be adversely affected by physical, chemical, biochemical and microbiological processes. Quality deterioration caused by microorganisms may include a wide range and types of spoilage that are undesirable commercially. The microbial contamination, however, can adversely affect the fruit quality and hence the final product quality (Lee, 2004).

Food preservation goes long back since the evolution of human beings. As the evolution progressed, so did the means and methods of food preservation. Various methods of control process namely, drying, heating, cooling, salting or pickling, pasteurisation or sterilisation, edible coating, application of MAP, CAP, electromagnetic radiation have been in use for this purpose. With passage of time, consumer's taste and perception of food have been changed, which could be linked to the increased buying power of the consumer and general awareness of the health benefits of fresh produce. With the decline interest in the intermediate moisture food for their saltiness, sugar retention, flavour and colour changes, consumers have started giving emphasis to the freshness of food, with minimum quality deterioration.

The concept of hurdle technology evolved through the idea of keeping the freshness of food intact. Multi-target approach is the essence of hurdle technology, while ensuring product quality by the application of milder but synergistically acting methods (Leistner, 1992). The original Hurdle concept hypothesises the existence of synergy between antimicrobial factors. Building on the idea of food interfering with microbial homeostasis as the hypothesis of food preservation, Leistner developed the hypothesis of the multi-target preservation of foods (Bidlas and Lambert, 2008) as a foundation for the multiple-hurdle concept. Homeostasis as quoted by Leistner and Gorris (1995) "is the constant tendency of microorganisms to maintain the stability and balance of their internal environment such as pH and osmotic strength in the cell". Up to now, more than 50 hurdles are applied for the preservation of foods, which include temperature, relative humidity, pH, water activity, acidity, redox potential, chemicals, antioxidants and preservatives. The food being subjected to milder processing treatments retains the product quality with minimal damage. The storage of high moisture food having high water activity, no longer became a constraint while practicing such mild processing methods. In this method, two or more mild methods of food preservation techniques are applied to the food, so as to create hurdles for the aforementioned spoilage causes. Therein facilitate the increased shelf life of food.

The hurdle technology concept was first applied to keep the freshness of meat (Leistner, 1992; 1994; 2000; Aymerich *et al*., 2008) and now-a-days its application has been extended to preservation of fresh, minimally processed and processed fruits (Alzamora *et al*., 1993), vegetables (Niemira *et al*., 2005), and dairy foods (Del Nobile *et al*., 2009; Walkling-Ribeiro *et al*., 2009). The major target of hurdle technology has been the microbial inactivation (Ross *et al*., 2003). The quantification of different parameters and their synergistic effect on the concept of hurdle technology has been addressed by response surface modelling, gamma and logistic modelling (Bidlas and Lambert, 2008). Application of hurdle technology for minimally processed foods has been reviewed by Alzamora *et al*. (1993). However, in this article focus will be on the shelf life extension of fresh fruits using hurdle technology.

Classification of fruits

Fruits are most liked food by the consumer all over the world, for their sweet taste, aroma and nutritive value. According to their geographical distribution they can be categorised into tropical, subtropical and temperate fruits.

Tropical fruits: Tropical fruits are grown in tropics and they cannot withstand slight chilling temperature. They require warm climate for fruiting.

Sub-tropical fruits: Subtropical fruits are grown in the sub tropics and Mediterranean's. They require warm or mild temperature but they can withstand mild frost.

Temperate fruits: These fruits are mainly grown in the temperature region (cold-winter) climates and require chilling temperature for the fruiting. They undergo dormancy in winter enabling them to tolerate freezing temperature and low photoperiods. During plant dormancy, visible growth is suspended and all physiological processes are halted or slowed (Luedeling, 2012). Some of the tropical, sub-tropical and temperate fruits are listed in Table 1.

Many of the fruits are seasonal in nature and highly perishable owing to their higher water content. Preserving the qualities of fresh fruits is very tedious as, several biochemical, metabolic, and microbial activities regulate the quality and shelf life of fruits.

They are harvested at full maturity and are self-sufficient to carry out further metabolic activities, such as respiration and ripening, even after being detached from the parent plant. Furthermore, the fruits are again classified into two major categories i.e. climacteric and non climacteric fruits, which have different biochemical and metabolic pathways, in addition to having different chemical composition.

Climacteric fruits: These fruits are characterised by high ethylene biosynthesis, after harvesting from the parent plants, which means the ripening continues even after harvesting. During ripening process of climacteric fruits, the levels of ethylene biosynthetic enzymes 1-aminocyclopropane-1-carboxylate (ACC) synthase (ACS) and ACC oxidase (ACO) increases (Yamane *et al*., 2007). Some of the major fruits of this category are listed in Table 2.

Non-climacteric fruits: The fruits neither synthesise enough ethylene during growth cycle nor does respond to external ethylene stimulus. So these fruits must be harvested from the parent plant when fully matured. Harvesting the fruits before they are fully matured will cause the uneven growth and quality degradation. The metabolic rates of these fruits are slower compared to the climacteric fruits (Prasanna *et al*., 2007). Most berries and citrus fruits come under this category (Table 2).

For both climacteric and non climacteric fruits, the ripening process is hastened by the addition of ethylene; nevertheless the ripening process can be delayed by flushing out naturally evolved ethylene through aeration.

Food spoilage causes

The fresh fruit can be spoiled by different factor i.e. microbial growth, biochemical changes such as ripening and respiration, caused by enzymatic activities. The major reasons of spoilage during storage could be attributed to the intrinsic properties of food, contamination during harvesting, handling and processing, mechanical wounds inflicting to enzymatic activity along with temperature abuse.

Microbial spoilage: Fruits can be contaminated with a wide range of microorganisms during harvesting, handling, transportation, and processing. Certain microflora are already present in the fruits prior to harvesting. Some of the microbes grow and spoil the produce during subsequent storage and distribution. The type of biochemical reactions followed or the microbial growth depend on the environmental factors and intrinsic properties of produce. For the past few decades public health concern has been largely attributed to contaminated fruits and vegetables. The different pathogens most frequently linked to fruit and vegetable produce-related outbreaks generally include bacteria such as *Escherichia coli O157: H7, Salmonella spp.* and *Listeria spp.* Many pathogens and bacteria including *Bacillus, Salmonella, Listeria, Staphylococcus,* and *Escherichia* are capable of adhering to and forming a biofilm on fruits and vegetable surfaces (Bilek and Turantaş, 2013).

Fruit ripening and quality degradation: Ripening is the one of the most complex plant metabolic pathway. The fruits undergo various changes i.e. translocation of nutrients, conversion of starch into sugar, phenolic compound development, increased respiration, chlorophyll degradation/ carotenoid and anthocyanin synthesis, degradation of flavanoids, tannins, pectin degradation, cell wall softening and most importantly ethylene biosynthesis. All these processes bring about desirable changes in texture, colour and aroma of the fruit. Most of these metabolic activities are governed by a plant hormone (Prasanna *et al*., 2007) ethylene. Ethylene regulates every stages of plant growth, from sprouting of seed to leaf development and from flowering to fruit maturity and ripening. These hormones are produced when triggered by wound, temperature or water stress, wind velocity etc. Ethylene expedite the ripening and respiration processes, causing senescence and cellular disintegration, hydrolysis of compounds, resulting in quality degradation, thus limiting the shelf life of the fruit. The ripening process can be divided into pre-climacteric and climacteric stages. During the pre-climacteric stage the ethylene production is slow, thus delaying the maturity and so does the respiration rate. During the climacteric stage, however, respiration rate increases and there is higher ethylene production in the plant cell.

Apart from quality degradation due to ripening, fruits suffer from chilling injury while in cold storage. In many cases the fruits are transported and stored below their recommended temperature and relative humidity. This result in browning of skin and pulp, leading to quality deterioration and eventually decrease in the market price of the fruits.

Preservation of fresh fruits

Inhibition of microbial load: Fresh fruit surface could be a host of various virus, bacteria, yeast and mold which are manifested at any phases of pre harvest and post harvest conditions. Microbial load of the fresh fruits or minimally processed fruits can be reduced by application of several non- thermal technologies such as pulsed electric fields (PEFs), ionizing radiation and-

Table 1: Classification of fruits based on geographical distribution

Tropical	Sub-tropical	Temperate
Acerola	Avocado	Apple
Banana	Fig	Apricot
Cashew apple	Dates	Blackberry
Cherimoya	Grapes	Blackcurrant
Custard Apple	Grape fruit	Blueberry
Dragon fruit	Lime	Cherry
Durian	Litchi	Gooseberry
Elephant apple	Olive	Grapes
Guava	Orange	Kiwi Fruit
Indian gooseberry	Mandarin	Nectarine
Jackfruit	Passion Fruit	Mulberry
Mango	Pomegranate	Peach
Papaya	Loquat	Pear
Pineapple	Longan	Melon
Sapote		Plum
Star apple		Quince
Sweetsop		Raspberry
Water melon		Strawberry

Table 2: Classification of fruits based on ethylene biosynthesis

Climacteric fruits	Non-Climacteric fruits
Apples	Blackcurrant
Apricots	Blueberry
Avocados	Carambola (star fruit)
Bananas	Cashew apple
Custard Apple	Cherry
Date	Cucumber
Figs	Grape
Guavas	Grapefruit
Honeydew melon	Lemon
Jack fruit	Litchi
Kiwi fruit	Lime
Mangoes	Longan
Musk melon	Loquat
Nectarines	Mandarin
Papaya	Melon
Passion fruit	Pineapple
Peaches	Pomegranate
Pears	Olive
Persimmons	Orange
Plum	Raspberry
Sapote	Strawberry

ultrasonication at ambient or sub-lethal temperatures. Many of these processes require very high treatment intensities; however, to achieve adequate microbial destruction in fresh fruits, combining non-thermal processes with conventional preservation methods significantly enhances their antimicrobial effect, so that lower process intensities can be used (Ross *et al*., 2003). For conventional preservation treatments, optimal microbial control is achieved through the hurdle concept, with synergistic effects resulting from different components of the microbial cell being targeted simultaneously with irradiation, radio frequency heating, microwave blanching, and O_3 treatment, at a lower level, so as to keep the quality degradation in the process in the form of loss of colour, texture and other essential nutrient to the minimum. The aforementioned processes can be coupled with application of essential oils, chemicals, cold storage/ refrigerated storage, freezing, aseptic packaging, edible coating, MAP, CAP, active packaging, pulsed UV light, irradiation, radio frequency heating, chlorine water etc.

Inhibition of respiration loss: Fresh fruits and vegetables continue to respire, even though detached from the parent plant, resulting in weight and moisture loss. In the respiration process, the glucose is oxidised to form CO_2 and moisture. Creating an oxygen deficit environment by the application of CAP or MAP would greatly reduce the respiration rate and thereby the moisture loss. In MAP, the storage environment is modified by allowing CO_2 to build up, ultimately restricting the availability of O_2 to the plant tissue. In CAP, however, constant CO_2 and O_2 ratio is maintained by purging CO_2 into the storage environment. The respiration rate can be decreased by storing the fresh produce at lower temperature, using MAP, CAP or active packaging methods. Though respiration rate can be lowered using such technologies, the water accumulation resulting from respiration can be a cause of microbial growth. This problem can be solved by using one or more desiccants in combination, in the MAP and CAPs (Mahajan *et al*., 2008).

Inhibition of ethylene biosynthesis: Ethylene biosynthesis can be controlled by maintaining low temperature, creating an oxygen deficit environment, increasing CO_2 concentration, blocking the ethylene generating sites by introduction of exogenous ethylene, applying ethylene biosynthesis inhibitors like vinyl glycine analogs, 1-methylcyclopropene (1-MCP), hydroxylamine analogs, Ca^{2+}, orthophosphate ions, cobalt chloride ($CoCl_2$), decouplers and membrane disruptive agents like 2,4-Dinitrophenol (DNP) and carbonyl cyanide m-chlorophenylhydrazone (CCCP) in small doses, free radical inhibitors such as n-propyl gallate and sodium benzoate and polyamines (Apelbaum *et al*., 1981; Yang and Hoffman, 1984).

Potential hurdles for fresh whole fruits preservation

In order to achieve the safe storability of the fresh fruits, the hurdle technology must comply with the multi-target methods. Post harvest, the fresh produce should be attended to ensuring the safety of the stored products. The fruits should be washed and sanitized properly prior to storage or packaging. Even hot water immersing, rinsing and brushing can decrease the microbial load to a significant level (Fallik, 2004). Some of the commonly used decontaminating and sanitizing agents are detergent products, chlorine, electrolyzed water, aqueous chlorine dioxide and acidified sodium chlorite, aqueous ozone, peroxyacetic acid, hydrogen peroxide, organic acids, alkaline products and iodine (Sapers, 2009). A few sanitizing agents, however, impart off flavour, colour and texture to the fresh fruits. Several antimicrobial washing solutions, O_3, UV–C radiation, super high O_2, hexanal, N_2O and noble gases alone or in combination, are presently considered as promising treatments (Utto *et al*., 2008; Artés *et al*., 2009).

Chlorine wash: The use of chlorine as a produce disinfectant is very common in the food industries. It is generally used in the following forms: chlorine gas, calcium hypochlorite and sodium hypochlorite and there has been much research into the efficacy of chlorine as a sanitizer for produce decontamination. There are public issues however, regarding the residual effect of chlorine on the fresh fruits and vegetable surfaces. Moreover, chlorine is not efficient in eliminating the biofilm forming bacteria. Goodburn and Wallace (2013) emphasized the use of chlorine as decontamination methods after reviewing various technologies for enhancing the storage lie of fresh produce. In some cases chlorine wash was found to be more effective against fungal infection than ozone (Crowe *et al*., 2012). Shin *et al*. (2012) when treated strawberries with 50 ppm aqueous chlorine dioxide and 5 kJ/m^2 ultraviolet-C irradiation and packed with rice bran protein film containing 1% grapefruit seed extract, observed a better microbial control. Chlorine is a common efficient sanitation agent but there is the risk of undesirable by-products upon reaction with organic matter and this may lead to new regulatory restrictions in the future. For example application of chlorine for decontamination of strawberries can result in off flavour development and anthocyanin degradation.

Moreover; its efficacy is poor for some products. Similarly application of H_2O_2 as sanitizer is well documented.

Hydrogen peroxide treatment: Hydrogen peroxide is an effective sanitizing agent and has been approved for food use. The oxidative as well sanitizing properties makes it an ideal choice for use in food industry. The effectiveness of this sanitizer has been documented for different blueberries, strawberries, lemon, and melon among others (Ukuku, 2004; Alexandre *et al*., 2012; Cerioni *et al*., 2013; Li and Wu, 2013). Li and Wu (2013) have studied the efficacy of this sanitizer in combination to retard the growth of *Salmonella* with other chemicals and recommended 0.5 mg/ml acetic acid plus 5000 ppm Sodiumdisulphide (SDS), 200 ppm hydrogen peroxide in combination with 5000 ppm SDS as an alternative to the use of chlorine-based washing solution for blueberries. Hydrogen peroxide treatment, however, imparts anthocyanin degradation in the pericarp of litchi (Ruenroengklin *et al*., 2009).

Application of chemicals: Application of chemicals like 1-methylcyclopropane (1-MCP), oxalic acid, inhibits chilling injury. 1-Methylcyclopropene (1-MCP) is an inhibitor of ethylene receptors and delays ripening of horticultural products. The use of 1-MCP is a potentially useful tool for commercial application to reduce the ripening process, senescence, retard fruit softening, alleviate chilling injury, maintain quality, and extend shelf life of fruit, vegetables, and ornamental species (Prasanna *et al*., 2007). 1-MCP treatment is now accepted for application as a ripening delaying agent. Inappropriate dosing might induce uneven colouring of the pericarp of fruits. Similarly application of oxalic acid, salicylic acid, methyl jasmonate and nitric oxide alleviates the chilling injury symptoms in various fruits like pomegranate (Sayyari *et al*., 2009), loquat (Cao *et al*., 2010), plum (Luo *et al*., 2011), tomato (Zhao *et al*., 2011), cucumber (Yang *et al*., 2011), mango (Li *et al*., 2014).

Ozone treatment: Ozone is a highly effective sanitizing agent. Application of both aqueous and gaseous ozone has been in use for decontaminating meat, poultry, fish, fruits and vegetables (Najafi and Khodaparast, 2009). Ozone has been known to reduce sprouting in potatoes and disinfesting tomatoes. During storage, if the temperature is not maintained, bacterial growth can resurface (Kim *et al*., 2003; Tzortzakis *et al*., 2008). Since ozone is an oxidising agent, it may impair off flavour or colour disintegration in anthocyanin containing fruits. Ozone could be seen as an alternative to refrigeration in order to enhance tomato shelf life in areas where cold facilities are not available. Zambre *et al*. (2010) has observed that shelf life of tomatoes can be enhanced by 12 days when ozone treated tomatoes were stored at 15°C. Ozone application has improved the antioxidant capacity of papaya fruit and it was observed that the sweetness and overall acceptability was better with ozone treated fruits. Thus ozone can be used as a non-thermal and safe preservation technique for papaya fruit (Ali *et al*., 2014). Overexposure of ozone may lead to off flavour development and environmental pollution. It may not be as effective as chlorine on certain fruits (Crowe *et al*., 2012).

Irradiation: For the marketing of raw or minimally processed foods, cold decontamination process is a requirement for effective management and control of the quality in the food chain. Irradiation is such a control measure in the production of several types of raw or minimally processed foods such as poultry, meat and meat products, fish, seafood, and fruits and vegetables. This technology ensures complete product safety from the vegetative form of pathogens as well as parasites and is aptly termed as cold pasteurisation. Irradiation is a safe technology and the critical limits of the doses are well established and can be corrected if necessary and have been recognized as such by the FAO/WHO Codex Alimentarius Commission. It certainly merits the attention of industry and public health authorities (Molins *et al*., 2001). Research on irradiation of several tropical fruits such as papayas, mangoes, litchi showed that the chemical, sensory and nutrient qualities of these fruits were well retained at 1.0 kGy, and the fruits would ripen normally or slightly delayed (Moy, 1003). Irradiation does of (0.3-0.7 kGy) reduced post harvest decay in mango. Higher gamma radiation dose (6-10 kGy), however, imparted radiation injury on the fruits like mango (Mahto and Das, 2013).

High voltage electric field: Existence of electrostatic force of repulsion has been first observed by Niccolo Cabeo in 1629. When sufficiently high electric field (AC or DC), in the order of kilovolts, in the domestic or industrial frequency range (50 or 60 Hz) is applied across the food, which is composed of complex molecules like carbohydrate, protein, fat, vitamins, polyglycerides and water, it polarizes the bipolar molecules (Mohapatra and Mishra, 2011). This phenomenon interferes with the metabolic pathways of fresh produce when treated with high voltage electric field (HVEF). Few studies have reported on the effect of HVEF on shelf-life of food materials. Toda (1990) (cited by Palanimuthu *et al*., 2009) treated lettuce, spinach and komatsuna with HVEF and observed a reduction in the respiration rates. Similarly results were reported by Kharel *et al*. (1996) for HVEF treated pear, plum, banana, apple and sweet pepper. Atungulu *et al*. (2004) observed the reduced rates of respiration in apple under HVEF. Bajgai *et al*. (2006) treated Emblic fruit (Phyllanthus emblica L.) with HYVF (430 kV/m) for 2 h and concluded that HVEF treated fruits have better freshness compared to untreated ones. Palanimuthu *et al*. (2009) observed that application of HVEF (2-8 KV/cm) reduced the respiration rate of cranberry and the weight loss was in the range of 23.2–30.4% after 3 weeks of storage. Most reports on HVEF application in food has concentrated on fluid foods; its application on solid fruits is limiting. Thus commercialization of this process would require much more information; therefore, research work.

Electromagnetic wave application: Decontamination using organic solutions and disinfectants can ensure the safety from the spoilage organisms clinging to the pericarp of the fruits, but some insects and viruses cannot be detected as they grow from the embryo or may be in dormant stage. Outwardly invisible, they may grow and spoil the fruits during storage if a homeostatics situation arises. In that case irradiation or electromagnetic wave propagation like microwave (MW), radiofrequency (RF) through the fresh fruits will be beneficial. Since the electromagnetic waves penetrate to a greater depth and result in volumetric heating. Mild heat treatment, such as MW, RF heating along with other decontamination treatment has a great potential in fresh fruit marketing (Ikediala *et al*., 2000; Zhang *et al*., 2006; Birla *et al*., 2004). Pulse UV (PUV) light also found to be effective in reducing microbial load for an exposure period of 10 s on a varieties of fruits including apples, kiwi, lemon, nectarines, oranges, peaches, pears, raspberries, and grapes (Lagunas-Solar*et al*., 2006). They have recommended PUV technique for commercial scale disinfection measures as non-chemical method; however, for maximum disinfection efficiency, coherent PUV sources must be combined with dispersing reflectors, and fruits must be handled to ensure uniform exposure to multidirectional incident beams. Application of UV-C treatment also alleviates the chilling injuries in fruits (Pongprasert *et al*., 2011). UV-C treatment has potential to delay postharvest fruit senescence and especially control decay in different fruit and vegetable species (Maharaj *et al*., 1999; Barka *et al*., 2000; Erkan *et al*., 2001; Marquenie *et al*., 2003; Allende and Artes, 2003; Allende *et al*., 2006). The exposure to UV-C delays fruit softening which is one of the main factors determining fruit postharvest life (Pan *et al*., 2004). Barka *et al*. (2000) found that UV-C decreased the activity of enzymes involved in tomato cell wall degradation and delayed the fruit softening. Reduction of strawberry fruit softening, less decay, and increase in phenoloc content by UV-C application has also been reported (Baka *et al*., 1999; Erkan *et al*., 2008).

Ultrasound application: Ultrasound is one of the newest non-thermal methods to extend shelf life of fresh fruits during storage. It is perceived as safer, non-toxic, environmental friendly process without any detrimental effect on human health. The effectiveness of ultrasound depends on wave frequency, power and treatment time. Sound waves carry acoustic energy and can be transmitted though pressure fluctuations in air, water or any other elastic media. These acoustic waves when encounter any deviation of particles from their mean position, they try to level it off; thereby passing some amount of energy to the next particle. So the disturbances go on in a cyclic manner, forming compression, through increase in pressure and rarefaction, though decrease in pressure, in the medium. Sound waves can be classified into three categories i.e. supersonic (frequency< 20 Hz), audible (20 Hz <frequency>20 kHz), or ultrasound (frequency>20 kHz). Ultrasound waves can again be classified into two categories, high frequency-low energy waves that are used for non destructive quality measurement and analysis and low frequency –high energy waves or power ultrasound. Power ultrasound usually refers to the frequency range between 20-40 kHz (Mohapatra and Mishra, 2011). Numerous studies have been attempted to explain the effect of ultrasound on fruits, vegetables (Bilek and Turantaş, 2013). Aday *et al*. (2013) demonstrated the effect of ultrasound on strawberry quality and concluded that ultrasound power levels of 30-60W for 5-10 min treatment time has resulted in improved quality and can be used to enhance the shelf life of the product. Ultrasound alone is not effective against microorganism; hence its application in combination with other treatments such as heat, pressure and chemical treatment will enhance its efficiency.

Hyperbaric pressure treatment: Hyperbaric treatment is a physical postharvest preservation technique in which fresh produce are subjected to an elevated pressure environment ranging from 0.1 to 1.0 MPa (Goyette *et al*., 2012). Recently, a few studies have shown that hyperbaric treatment provides beneficial effects on extending the shelf-life of some fruits and vegetables such as sweet cherries, peach, strawberries, mume fruit, apple, tomato, mango and Japanese pear among others. Baba *et al*. (2003) showed that shelf life of mume fruit subjected to 0.5 MPa for 5 days was prolonged through suppression of respiratory CO_2 and ethylene production. It was also reported that pressure treatment could maintain a commercially acceptable color quality, reduce weight loss, and protect against chilling injuries. Romanazzi *et al.* (2001, 2008) studied the effect of short hyperbaric treatments on postharvest decay of sweet cherries, strawberries, and table grapes and found that the incidence of brown rot, gray and blue mold, and total rot was greatly reduced after storage at 20°C. Hyperbaric pressure treatment (0.3 to 0.9 Mpa) of tomatoes, during storage could reduce respiration rate and maintain freshness and quality attributes of tomato fruit, with enhanced lycopene content was at the end of ripening period (Goyette, 2010; Goyette *et al.*, 2012; Liplap *et al.*, 2013a,b). A hypobaric pressure (50 kPa, 4 h) treatment of strawberries reduced the fungal rot (Hashmi *et al.*, 2013a) and the cause of delayed decay was attributed due to stimulation of defence-related enzymes (Hashmi *et al.*, 2013b). Hypobaric pressure treatment has potential as an alternative non-chemical postharvest disinfestation method for fresh fruits; the cost factor however prohibits traders to adopt it commercially.

Active packaging–MAP/CAP/CAS: On decontamination, the fresh produce can be further stored in active packaging system. Active packaging is a new concept that has arisen as a response to continuous consumer demand and market trend. This technique concerns with the substances that adsorb/absorb CO_2, O_2, flavour/odours, moisture, ethylene and those microbes that release CO_2, antimicrobial agents and antioxidants (Vermeiren *et al.*, 1999). The O_2, CO_2, ethylene scavengers and microbial agents are placed inside the packaging system, so as to effectively improve the packaging environment. The essential oil extracted from spices and plants have anti fungal and anti microbial properties, those can be suitably used in active packaging system without impairing any off odour to the product. Plasticized protein coating on polypropylene films works as antimicrobial agent when incorporated with nisin and whey protein isolate, the films with bacteriocins absorber can be used as an active packaging film (Scannell *et al.*, 2000; Lee *et al.*, 2008). High or low level of O_2 concentration or passive modified atmospheric packaging system is usually adopted in these cases. However, the high O_2 may induce oxidative reaction, resulting in product quality deterioration (Zheng *et al.*, 2007). They recommended to optimize the O_2 concentration for each produce. MAP when combined with other pre-treatments such 1-MCP, essential oil enhances the shelf life of litchi, sweet cherry, table grapes (Sivakumar *et al.*, 2008, De Reuck *et al.*, 2009; Sivakumar and Korsten, 2006; 2010; Serrano *et al.*, 2008). Active, MAP or CAP too have their fallouts. Disbalance in the atmospheric condition could lead to fermentation and off flavour development in the fruits.

Edible film: Edible coating are now been extensively used in storing both processed, minimally processed and fresh whole fruits and vegetables. The edible coatings are chosen keeping in view of the future needs, such as in case of active packaging system where, the film material can react with the food component and prevents undesirable changes. The edible coating can also be used to deliver certain bioactive compounds into the food system. The edible films could be based on fruit (apple puree), vegetable starch (pumpkin), fruit wax, gum cordia, gum Arabic, pectin, carboxymethyl cellulose, chitosan, algenate, whey protein isolate aloe-vera gel with antimicrobial properties (Martínez-Romero *et al.*, 2006; Rojas-Graü *et al.*, 2007; Sothornvit and Pitak, 2007; Sothornvit and Rodsamran, 2008, Saucedo-Pompa *et al.*, 2009; Haq *et al.*, 2013; Lago-Vanzela *et al.*, 2013; Arnon *et al.*, 2014). The edible films have poor mechanical and barrier properties when compared to synthetic polymers, which have lead to the reinforcement of nanocomposites in to biopolymers for improving their properties and enhancing their cost-price-efficiency. However, there are many safety concerns about nanomaterials, as their size may allow them to penetrate into cells and eventually remain in the human organism. While the properties and safety of the materials in their bulk form are usually well known, the nano-sized counterparts frequently exhibit different properties from those found at the macroscale, and there is limited scientific data about their eventual toxicological effects. So the need for accurate information on the effects of nanomaterials on human health following chronic exposure is imperative before any nanostructured food packaging is available for commercialization (Falguera *et al.*, 2011).

Essential oils and phenolics: Plant essential oils and phenolics are antioxidants and their use in Indian cuisine is centuries old. With growing awareness on Indian food and their beneficial effect on health has promoted the use of spices in the food system. Of late significant research is being conducted on the spices and the essential oils derived from them like vanillin. For their antioxidant properties, the essential oils derived from spices and other plant phenolic compounds can be used as coating or in the packaging film ingredient for enhancing storage life as well as to adsorb off orders. These compounds have been included in the list of generally recognized as safe (GRAS) compounds by FDA (Serrano *et al.*, 2005). Though these plant derivatives are regarded as safe and can be used in place of chemical agents, their commercial viability is yet to be chalked out.

Bacteriocins: Bacteriocins are basically proteinaceous toxic compounds, produced by different groups of bacteria to inhibit the growth of similar or closely related bacterial strain. Many lactic acid bacteria (LAB) produce bacteriocins with rather broad spectra of inhibition. Several LAB bacteriocins offer potential applications in food preservation, and the use of bacteriocins in the food industry can help to reduce the addition of chemical preservatives as well as the intensity of heat treatments, resulting in foods which are more naturally preserved and richer in organoleptic and nutritional properties. In addition to the available commercial preparations of nisin and pediocin PA-1/AcH, other bacteriocins (like for example lacticin 3147, enterocin AS-48 or variacin) also offer promising perspectives. Broad-spectrum bacteriocins present potential wider uses, while narrow-spectrum bacteriocins can be used more specifically to selectively inhibit certain high-risk bacteria in foods like *Listeria monocytogenes* without affecting harmless microbiota. Bacteriocins can be added to foods in the form of concentrated preparations as food preservatives, shelf-life extenders, additives or ingredients, or they can be produced in situ by bacteriocinogenic starters, adjunct or protective cultures. Immobilized bacteriocins can also find application for development of bioactive food packaging. In recent years, application of bacteriocins as part of hurdle technology has gained great attention. Several bacteriocins show synergistic effects when used in combination with other antimicrobial agents, including chemical preservatives, natural phenolic compounds, as well as other antimicrobial proteins. This, as well as the combined use of different bacteriocins may also be an attractive approach to avoid development of resistant strains. The effectiveness of bacteriocins is often dictated by environmental factors like pH, temperature, food composition and structure, as well as the food microbes (Gálvez *et al*., 2007). Martínez-Castellanos *et al*. (2011) demonstrated the quality preservation of litchi by application of *Lactobacillus plantarum*. Bacteriocins can be the used in active packaging films or in edible coating for the fresh whole fruits. Cao *et al*. (2011) has observed the synergistic effect of benzo-thiadiazole-7-carbothioic acid S-methyl ester (BTH) on a biocontrol agent Pichiamembranefaciens in controlling postharvest blue mould decay in peach fruit. Liu *et al*. (2013) has reviewed the potential of lactic acid bacteria as biocontrol agent against the pathogenic bacteria, responsible for fruit decay. Some pathogenic bacteria develop bacteriocin resistance; moreover the dynamics of bacteriocin action depends on the type of fruit and microflora, thereby limiting its efficacy.

Storage temperature: It is well known fact that temperature has a great say whilst several preservation technology has been developed for food preservation.
Application of heat during blanching/pasteurisation or removal of heat during refrigeration has long been practiced in the food industry. In case of fresh fruits, storage temperature is of utmost importance as this parameter decides the viability and growth probability of microorganisms. Since microbes require optimal temperature and water activity for survival and growth, storage at suboptimal temperature conditions enhances the product storage life. As previously discussed, the biochemical reactions affecting the fresh fruits quality also require optimal temperature for the post harvest changes; can be affected or in some cases delayed under low temperature storage, which has been demonstrated by various researchers for fresh fruits such as pears (Villalobos *et al*., 2011), banana (Khanbarad *et al*., 2012), pineapple (Hong *et al*., 2013). Some fruits however, are prone to chilling injuries, marked by browning of the skin and pulp and loss of flavour. In many cases fruits are stored and transported below the optimal temperature, which results in quality deterioration.

Storage relative humidity: When fruits are stored under higher relative humidity, it affects the desiccation and shrivelling of peels of the fruits and in some cases improves the shelf life, as such high relative humidity also favours growth of fungus and molds, therefore should be combined with low temperature storage. Sharkey and Peggie (1984) had observed that the shelf life of cherries and lemons was extended when they were stored under high relative humidity (95-99 %). in most citations relative humidity is combined with temperature of storage and does not have pronounced effect on the fruit quality (Shin *et al*., 2008). Recommended temperature and relative humidity of storage for different fruits (FAO, 2013) are presented in Table 3.

Pre-cooling: Pre-cooling fruits and vegetable to remove field heat has been in practice since long. It reduces the metabolic rate and improves the shelf life of commodity. Tatsuki *et al*. (2011) applied pre-cooling for 24 h at -1 or -3°C followed by 1 MCP treatment to Tsugaru apple. The fruits were observed for their ethylene production, firmness, and acidity. The pre-cooled fruits maintained high acidity and firmness with low level of ethylene synthesis.

Table 3: Recommended temperature and relative humidity for fruits and the approximate storage life under these conditions.

Fruit	Storage Temperature (°C)	Storage Relative Humidity (%)	Storage life (days)
Apple	-1-4	90-95	30-180
Apricot	-0.5-0	90-95	7-21
Asian pear	1	90-95	150-180
Atemoya	13	85-90	28-42
Avocado	3-13	85-90	14-56
Babaco	7	85-90	7-21
Banana /Plantain	13-15	90-95	7-28
Barbados cherry	0	85-90	49-56
Blackberry	-0.5-0	90-95	2-3
Black sapote	13-15	85-90	14-21
Blueberries	-0.5-0	90-95	14
Breadfruit	13-15	85-90	14-42
Caimito	3	90	21
Calamondin	9-10	90	14
Cantalupo	0-2	95	5-15
Carambola	9-10	85-90	21-28
Cashew apple	0-2	85-90	35
Chayote	7	85-90	28-42
Cherimoya	13	90-95	14-28
Cherries	-1-0.5	90-95	14-21
Chicory	0	95-100	14-21
Coconut	0-1.5	80-85	30-60
Cranberries	2-4	90-95	60-120
Cucumber	10-13	95	10-14
Currants	-0,5-0	90-95	7-28
Custard apple	5-7	85-90	28-42
Dates	-18-0	75	180-360
Durian	4-6	85-90	42-56
Feijoa	5-10	90	14-21
Fig	-0.5-0	85-90	7-10
Grape	-0.5-0	90-95	14-56
Grapefruit	10-15	85-90	42-56
Guanabana	13	85-90	7-14
Guava	5-10	90	14-21
Jaboticaba	13-15	90-95	2-3
Jackfruit	13	85-90	14-42
Kiwano	10-15	90	180
Kiwifruit	-0.5-0	90-95	90-150
Kumquat	4	90-95	14-28
Lemon	10-13	85-90	30-180
Lime	9-10	85-90	42-56
Longan	1-2	90-95	21-35
Loquat	0	90	21
Lychee	1-2	90-95	21-35
Mamey	13-18	85-95	14-42
Mandarin	4-7	90-95	14-28
Mango	13	90-95	14-21
Mangosteen	13	85-90	14-28
Melon	7-10	90-95	12-21
Nectarine	-0.5-0	90-95	14-28
Olives, fresh	5-10	85-90	28-42
Orange	0-9	85-90	56-84
Papaya	7-13	85-90	7-21
Passionfruit	7-10	85-90	21-35
Peach	-0.5-0	90-95	14-28

Pear	-1.5-0.5	90-95	60-210
Cucumber	5-10	95	28
Persimmon	-1	90	90-120
Pineapple	7-13	85-90	14-28
Pitaya	6-8	85-95	14-21
Plum	-0.5-0	90-95	14-35
Pomegranate	5	90-95	60-90
Prickly pear	2-4	90-95	21
Quince	-0.5-0	90	60-90
Rambutan	10-12	90-95	7-21
Raspberries	-0.5-0	90-95	2-3
Sapodillla	15-20	85-90	14-21
Strawberry	0-0.5	90-95	5-7
Tart cherries	0	90-95	3-7
Tomato (MG)	12.5-15	90-95	14-21
Tomato (red)	8-10	90-95	8-10
Tree tomato	3-4	85-90	21-28
Watermelon	10-15	90	14-21
White sapote	19-21	85-90	14-21
Yellow sapote	13-15	85-90	21

(Source: FAO, 2013)

Table 4: Hurdles applied to different fresh fruits for extension of shelf life

Fruits	Treatments	Shelf life extension/microbial inactivation	References
Apple	gamma irradiation (200–400 Gy)+ biocontrol agent (Pseudomonas fluorescens)	Improved quality in 3 months storage period than control	Mostafavi *et al.*, 2013
	Harvest maturity (190 days after blossoming)+ low (0-1°C temperature) + CA (1–2 kPa O2/<1 kPa CO2)	Less flesh browning after 2 months storage	Kweon *et al.*, 2013
Avocado	1-MCP+ waxing	Delayed ripening after 19days	Jeong *et al.*, 2003
Banana	1-MCP (0.5µl/l)+ polyethylene bagging	58 days	Jiang *et al.*, 1999
	1-MCP (1000 nL/ L for 4 h at 25 °C)+ non-perforated PE (MAP)	100 days	Ketsa *et al.*, 2013
Blueberry	100 mg/L chlorine or 1 mg/L aqueous ozone+air blast freezing (60 s), storage at 18°C	12 months	Crowe *et al.*, 2012
Cherry	Essential oil+ MAP	Delayed decay after 16 days storage	Serrano *et al.*, 2005
	Aleovera coating+ low temperature (1°C, 96 %RH)	Less loss of quality	Martínez-Romero *et al.*, 2006
	Hexanal vapour +1 MCP	30days	Sharma *et al.*, 2010
Carambola	MAP +low temperature (10°C)	Delayed solubilization and loss of firmness after 21days	Ali *et al.*, 2004
Dates	UV-C and neutral electrolyzed water (pH 7.2, ORP 814 mV, and 300 mg L^{-1} of free chlorine)	30 days storage life	Jemni *et al.*, 2014
Grape	MAP+essential oil	56 days	Valero *et al.*, 2006
Kiwi fruit	MAP+coating with sodium algenate	13 days	Mastromatteo *et al.*, 2011
Lemon	H_2O_2+hotwater+ hydrogen peroxide followed by potassium phosphate	Control of mold and rot	Cerioni *et al*, 2013

Litchi	sodium hypochlorite, potassium metabisulfite, hydrochloric acid and ascorbic acid dip+gamma does 92.4 kGy)	30-45 days	Kumar *et al*., 2012
	1% NaCl+2% wax coating+1 Kgy radiation dose	24 days	Pandey *et al*., 2013
Mango	Dipping in hot 0·5% $Na_2S_2O_5$+ packaging in boxes overwrapped with stretch PVC film	Delayed ripening	Joseph and Aworh, 1992
papaya	Methyl jasmonateMJ at 10^{-5} M+ MAP (3–5 kPa O2 and 6–9 kPa CO2) at 10°C	14-32 days	González-Aguilar *et al*., 2003
Peach	Ultrasound (40 kHz, 8.8 W/L, 10 min)+ salicylic acid (0.05 mM)	6 days	Yang *et al*., 2011
	38 °C for 12 h + 1 µmol L−1 Methyl jasmonate vapor at 20 °C for 24 h	Chilling injury suppressed for 3 weeks storage	Jin *et al*., 2009
Pear	Gamma dose (1.5-1.7 kGy)+refrigerated storage (3±1 °C, RH 80%)	8 days extension	Wani *et al*., 2008
Plum	aqueous chlorine dioxide (40mgL^{-1} ClO_2 for 10 min) + ultrasound (100W for 10 min)	60 days	Chen and Zhu, 2011
	0.5 µL L−1 1-MCP at 0 °C for 24 h followed by storage at 10°C	30 days	Minas *et al*., 2013
Pomegra-nate	Shrink wrapping+8°C storage temperature	12 weeks	Nanda *et al*., 2001
Sapote	Brushing, Wax coating, 1-MCP treatment	14 days	Ergun *et al*., 2005
Strawberry	Perforated LDPE (10 µm thickness) +low temperature (0°C)	15 days	Guerreiro *et al*., 2013
	UV-C light (1 kJ m^{-2}), gaseous O3 (5000 mg L^{-1}) and two active MAP conditions (superatmospheric O_2 and CO_2-enriched atmospheres)	Delayed	Villalobos *et al*., 2011
	Calcium dip +chitosan coating	4days-week for storage temperatures of 20 and 10°C	Hernández-Muñoz *et al*., 2006, 2008
Saskatoon fruit	Low temperature (0.4°C) +2% O2	Quality maintained after 10 days	Rogiers and Knowles, 1998
Tomato	0.1 MPa pressure+ low temperature (13 °C)	Retention of firmness after 5 days	Liplap *et al*., 2013a,b
Cherry tomato	5–30 mg/l ozone gas for 0–20 min +MAP (6% O_2/4% CO_2), stored at 7°C	Salmonella Enteritidis died within 6 days	Das *et al*., 2006

Though the parameters discussed above has been effective in extending the shelf life of fresh fruits, when applied individually, their synergistic effect when combined with one or more parameters have been proved beneficial too. In the Table 4, some references on fresh whole fruits preservation using hurdle technology by employing two or more hurdles, is delineated.

Conclusions

Different hurdles are discussed vis-a vis extending the shelf life of fresh produce. Though more than 100 hurdles are practiced for food preservation; only a handful could be applied for the storage of fresh fruits. Milder doses of irradiation doses and storage at sub-optimal temperature would reduce the microbial load and inhibit ethylene biosynthesis; thus prolonging the shelf life. Application of organic acids, antimicrobial enzymes, chitin/chitosan, nisin, lactoferin, plant –derived antimicrobials, ozone, reuterin, electrolysed water, edible coating or MAP/CAP for the inhibition of other metabolic activities such as respiration would be suitable for climacteric fruits. Sanitizing agents for inhibiting Micro-flora could be chlorine water, intense light pulses, super high O_2, N_2O and noble gases. For climacteric fruits care should be taken while choosing the packaging system. During the storage the fruits respire and leave out CO_2 and H_2O. This builds up CO_2 in the package, thus inducing ethylene biosynthesis. Ethylene production in large amount may cause uneven ripening of the fruits.

For non climacteric fruits, application of plant essential oils as anti microbial agent or any of the anti-microbial treatment such as irradiation, chemical treatment, application of O_3, bacteriocins, essential oils, phenolics, microwave blanching, infrared and radio frequency heating would be sufficient, CAP, MAP, active packaging when stored at suboptimal temperature and relative humidity conditions can delay the respiration rate and senescence.

References

Aday MS, Temizkan R, Büyükcan MB and Caner C (2013). An innovative technique for extending shelf life of strawberry: Ultrasound. LWT - *Food Science and Technology,* 52: 93-101.

Alexandre EMC, Brandão TRS and Silva CLM (2012). Assessment of the impact of hydrogen peroxide solutions on microbial loads and quality factors of red bell peppers, strawberries and watercress. *Food Control,* 27: 362-368.

Ali A, Ong, MK and Forney CF (2014). Effect of ozone pre-conditioning on quality and antioxidant capacity of papaya fruit during ambient storage. *Food Chemistry,* 42: 19-26.

Ali ZM, Chin L-H, Marimuthu M and Lazan H (2004). Low temperature storage and modified atmosphere packaging of carambola fruit and their effects on ripening related texture changes, wall modification and chilling injury symptoms. *Postharvest Biology and Technology,* 33: 181-192.

Allende A and Artes F (2003). UV-C radiation as a novel technique for keeping quality of fresh processed 'Lollo Rosso' lettuce. *Food Research International,* 36: 739–746.

Allende A, McEvoy JL, Luo Y, Artes F and Wang CY (2006). Effectiveness of two-sidedUV-C treatments in inhibiting natural microflora and extending the shelf-life of minimally processed 'Red Oak Leaf' lettuce. *Food Microbiology,* 23: 241–249.

Alzamora SM, Tapia MS, Argaíz A and Welli J (1993). Application of combined methods technology in minimally processed fruits. *Food Research International,* 26: 125-130.

Apelbaum A, Wang SY, Burgoon AC, Baker JE and Lieberman M (1981). Inhibition of the conversion of 1 -aminocyclopropane-1 -carboxylic acid to ethylene by structural analogs, inhibitors of electron transfer, uncouplers of oxidative phosphorylation, and free radical scavengers. *Plant Physiology,* 67: 74-79.

Arnon H, Zaitsev Y, Porat R and Poverenov E (2014). Effects of carboxymethyl cellulose and chitosan bilayer edible coating on postharvest quality of citrus fruit. *Postharvest Biology and Technology,* 87: 21-26.

Artés F, Gómez P, Aguayo E, Escalona V and Artés-Hernández F (2009). Sustainable sanitation techniques for keeping quality and safety of fresh-cut plant commodities. *Postharvest Biology and Technology,* 51: 287-296.

Atungulu G, Nishiyama Y and Koide S (2004). Respiration and climacteric patterns of apples treated with continuous and intermittent direct current electric field. *Journal of Food Engineering,* 63: 1–8.

Aymerich T, Picouet PA and Monfort JM (2008). Decontamination technologies for meat products. *Meat Science,* 78: 114–129.

Baba T, Ikeda F, Hewett E W and Prange RK (2003). Use of high pressure treatment to prolong the postharvest life of mume fruit (Prunus mume). *Acta Horticulturae,* 628: 373-377.

Bajgai TR, Hashinaga F, Isobe S, Raghavan GSV and Ngadi MO (2006). Application of high electric field (HEF) on the shelf-life extension of emblic fruit (Phyllanthus emblica L.). *Journal of Food Engineering,* 74: 308-313.

Baka M, Mercier J, Corcuff F, Castaigne F and Arul J (1999). Photochemical treatment to improve storability of fresh strawberries. *Journal of Food Science,* 64: 1068–1072.

Barka EA, Kalantari J, Makhlouf J and Arul J (2000). Impact of UVC illumination on the cell wall-degrading enzymes during ripening of tomato (*Lycopersicon esculentum* L.) fruit. *Journal of Agricultural and Food Chemistry,* 48: 667–671.

Bidlas E and Lambert RJW (2008). Quantification of hurdles: Predicting the combination of effects — Interaction vs. non-interaction. *International Journal of Food Microbiology,* 128: 78–88.

Bilek SE and Turantaş F (2013). Decontamination efficiency of high power ultrasound in the fruit and vegetable industry, a review. *International Journal of Food Microbiology,* 166: 155-162.

Birla SL, Wang S, Tang J and Hallman G (2004). Improving heating uniformity of fresh fruit in radio frequency treatments for pest control Postharvest *Biology and Technology,* 33: 205-217.

Cao S, Yang Z, Hu Z and Zheng Y (2011). The effects of the combination of Pichiamembranefaciens and BTH on controlling of blue mould decay caused by Penicilliumexpansum in peach fruit. *Food Chemistry,* 124: 991-996.

Cao S, Zheng Y, Wang K, Rui H and Tang S (2010). Effect of methyl jasmonate on cell wall modification of loquat fruit in relation to chilling injury after harvest. *Food Chemistry,* 118: 641-647.

Cerioni L, Sepulveda M, Rubio-Ames Z, Volentini SI, Rodríguez-Montelongo L, Smilanick JL, Ramallo J and Rapisarda VA (2013). Control of lemon postharvest diseases by low-toxicity salts combined with hydrogen peroxide and heat. *Postharvest Biology and Technology,* 83: 17-21.

Chen Z and Zhu C (2011). Combined effects of aqueous chlorine dioxide and ultrasonic treatments on postharvest storage quality of plum fruit (Prunussalicina L.). *Postharvest Biology and Technology,* 61: 117-123.

Crowe KM, Bushway A and Davis-Dentici K (2012). Impact of postharvest treatments, chlorine and ozone, coupled with low-temperature frozen storage on the antimicrobial quality of low bush blueberries (Vacciniumangustifolium). LWT - *Food Science and Technology,* 47: 213-215.

Crowe, KM, Bushway A and Davis-Dentici K (2012). Impact of postharvest treatments, chlorine and ozone, coupled with low-temperature frozen storage on the antimicrobial quality of lowbush blueberries (Vaccinium angustifolium). LWT - *Food Science and Technology,* 47: 213-215.

Daş E, Gürakan, GC and Bayındırlı, A (2006). Effect of controlled atmosphere storage, modified atmosphere packaging and gaseous ozone treatment on the survival of Salmonella Enteritidis on cherry tomatoes. *Food Microbiology,* 23: 430-438.

De Reuck K, Sivakumar D and Korsten L (2009). Integrated application of 1-methylcyclopropene and modified atmosphere packaging to improve quality retention of litchi cultivars during storage. *Postharvest Biology and Technology,* 52: 71-77.

Del Nobile MA, Gammariello D, Conte A and Attanasio M (2009). A combination of chitosan, coating and modified atmosphere packaging for prolonging Fior di latte cheese shelf life. *Carbohydrate Polymers,* 78: 151-156.

Ergun M, Sargent SA, Fox AJ, Crane JH and Huber DJ (2005). Ripening and quality responses of mamey sapote fruit to postharvest wax and 1-methylcyclopropene treatments. *Postharvest Biology and Technology,* 36: 127-134.

Erkan M, Wang SY and Wang CY (2008). Effect of UV treatment on antioxidant capacity, antioxidant enzyme activity and decay in strawberry fruit. *Postharvest Biology and Technology,* 48: 163–171.

Erkan, M., Wang, C.Y., Krizek, D.T. (2001). UV-C radiation reduces microbial populations and deterioration in Cucurbita pepo fruit tissue. *Environmental and Experimental Botany,* 45: 1–9.

Falguera V, Quintero JP, Jiménez A, Muñoz JA and Ibarz A (2011). Edible films and coatings: Structures, active functions and trends in their use. *Trends in Food Science and Technology,* 22: 292-303.

Fallik E (2004). Prestorage hot water treatments (immersion, rinsing and brushing). *Postharvest Biology and Technology,* 32:125-134.

FAO (2013) http://www.fao.org/docrep/008/y4893e/y4893e06.htm website accessed on 21-11-2013.

Gálvez A, Abriouel H, López RL and Omar NB (2007). Bacteriocin-based strategies for food biopreservation. *International Journal of Food Microbiology,* 120: 51-70.

González-Aguilar GA, Buta JG and Wang CY (2003). Methyl jasmonate and modified atmosphere packaging (MAP) reduce decay and maintain postharvest quality of papaya 'Sunrise'. *Postharvest Biology and Technology,* 28: 361-370.

Goodburn C and Wallace CA (2013). The microbiological efficacy of decontamination methodologies for fresh produce: A review. *Food Control,* 32: 418-427.

Gould GW (1996). Methods for preservation and extension of shelf life. *International Journal of Food Microbiology,* 33: 51-64.

Goyette B (2010). Hyperbaric treatment to enhance quality attributes of fresh horticultural produce. *McGill University, Montréal, Canada.*

Goyette B, Vigneault C, Charles MT and Raghavan GSV (2012). Effect of hyperbaric treatments on the quality attributes of tomato. *Canadian Journal of Plant Science,* 92: 541–551.

Guerreiro AC, Gago CML, Miguel MGC and Antunes MDC (2013). The effect of temperature and film covers on the storage ability of Arbutus unedo L. *fresh fruit. Scientia Horticulturae,* 159: 96-102.

Hashmi MS, East AR, Palmer JS and Heyes JA (2013a). Pre-storage hypobaric treatments delay fungal decay of strawberries. *Postharvest Biology and Technology,* 77: 75-79.

Hashmi MS, East AR, Palmer JS and Heyes JA (2013b). Hypobaric treatment stimulates defence-related enzymes in strawberry. *Postharvest Biology and Technology,* 85: 77-82.

Haq MA, Alam MJ and Hasnain A (2013). Gum Cordia: A novel edible coating to increase the shelf life of Chilgoza (Pinus gerardiana). LWT - *Food Science and Technology,* 50: 306-311.

Hernández-Muñoz P, Almenar E, Del Valle V, Velez D and Gavara R (2008). Effect of chitosan coating combined with postharvest calcium treatment on strawberry (Fragaria × ananassa) quality during refrigerated storage. *Food Chemistry,* 110: 428-435.

Hernández-Muñoz P, Almenar E, María José Ocio MJ and Gavara R (2006). Effect of calcium dips and chitosan coatings on postharvest life of strawberries (Fragaria x ananassa). *Postharvest Biology and Technology*, 39: 247-253.

Hong K, Xu H, Wang J, Zhang L, Hu H, Jia Z, Gu He HQ and Gong D (2013). Quality changes and internal browning developments of summer pineapple fruit during storage at different temperatures. *Scientia Horticulturae,* 151: 68-74.

Ikediala JN, Hansen JD, Tang J, Drake SR and Wang S (2002). Development of a saline water immersion technique with RF energy as a postharvest treatment against codling moth in cherries. *Postharvest Biology and Technology,* 24: 209-221.

Jemni M, Otón M, Ramirez, JG, Artés-Hernández F, Chaira N, Ferchichi A and Artés F (2014). Conventional and emergent sanitizers decreased Ectomyeloisceratoniae infestation and maintained quality of date palm after shelf-life. *Postharvest Biology and Technology,* 87: 33-41.

Jeong J, Huber DJ and Sargent SA (2003). Delay of avocado (Perseaamericana) fruit ripening by 1-methylcyclopropene and wax treatments. *Postharvest Biology and Technology,* 28: 247-257.

Jiang Y, Joyce DC and Macnish AJ (1999). Extension of the shelf life of banana fruit by 1-methylcyclopropene in combination with polyethylene bags. *Postharvest Biology and Technology,* 16: 187-193.

Jin P, Zheng Y, Tang S, Rui H, Wang CY (2009). A combination of hot air and methyl jasmonate vapor treatment alleviates chilling injury of peach fruit. *Postharvest Biology and Technology,* 52: 24-29.

Joseph K and Aworh, OC (1992). Post-harvest treatment of wild mango (Irvingiagabonensis) for improved shelf life. *Food Chemistry,* 44: 45-48.

Ketsa S, Wisutiamonkul A and van Doorn WG (2013). Apparent synergism between the positive effects of 1-MCP and modified atmosphere on storage life of banana fruit. *Postharvest Biology and Technology,* 85: 173-178.

Khanbarad SC, Thorat ID, Mohapatra D, Sutar RF and Joshi DC (2012). Effect of temperature and period of storage on physical, biochemical and textural properties of banana during ripening. *Journal of Dairying, Foods and Home Sciences,* 31: 212-215.

Kharel GP, Hashinaga F and Shintani R (1996). Effect of high electric field on some fruits and vegetables. *Journal of the Japanese Society for Cold Preservation of Food,* 22: 17–22.

Kim J-G, Yousef AE and Khadre MA (2003). Ozone and its current and future application in the food industry. *Advances in Food and Nutrition Research,* 45: 167-218.

Kumar S, Mishra BB, Saxena S, Bandyopadhyay N, More V, Wadhawan S, Hajare SN, Gautam S and Sharma A (2012). Inhibition of pericarp browning and shelf life extension of litchi by combination dip treatment and radiation processing. *Food Chemistry,* 131: 1223-1232.

Kweon H-J, Kang I-K, Kim M-J, Lee J, Moon Y-S, Choi C, Choi DG and Watkins CB (2013). Fruit maturity, controlled atmosphere delays and storage temperature affect fruit quality and incidence of storage disorders of 'Fuji' apples. *Scientia Horticulturae,* 157: 60-64.

Lago-Vanzela ES, Nascimento Pdo, Fontes EAF, Mauro MA and Kimura M (2013). Edible coatings from native and modified starches retain carotenoids in pumpkin during drying. LWT - *Food Science and Technology,* 50: 420-425.

Lagunas-Solar MC, Piña C, MacDonald JD and Bolkan L (2006). Development of pulsed UV light processes for surface fungal disinfection of fresh fruits. *Journal of Food Protection,* 69: 376-384.

Lee J-W, Son S-M and Hong S-I (2008). Characterization of protein-coated polypropylene films as a novel composite structure for active food packaging application. *Journal of Food Engineering,* 86: 484-493.

Lee S-Y (2004). Microbial safety of pickled fruits and vegetables and hurdle technology, *Internet Journal of Food Safety,* 4: 21-32.

Leistner L (1992). Food preservation by combined methods. *Food Research International,* 25: 151-158.

Leistner L (1994). Further developments in the utilization of hurdle technology for food preservation. *Journal of Food Engineering,* 22: 421-432.

Leistner L (2000). Basic aspects of food preservation by hurdle technology. *International Journal of Food Microbiology,* 55: 181–186.

Leistner L and Gorris LGM (1995). Food preservation by hurdle technology. *Trends in Food Science and Technology,* 6: 41–46.

Li P, Zheng X, Liu Y and Zhu Y (2014). Pre-storage application of oxalic acid alleviates chilling injury in mango fruit by modulating proline metabolism and energy status under chilling stress. *Food Chemistry,* 142: 72-78.

Li Y and Wu C (2013). Enhanced inactivation of Salmonella Typhimurium from blueberries by combinations of sodium dodecyl sulfate with organic acids or hydrogen peroxide. *Food Research International,* 54: 1553-1559.

Liplap P, Charlebois D, Charles MT, Toivonen P, Vigneault C and Raghavan GSV (2013a) Tomato shelf-life extension at room temperature by hyperbaric pressure treatment. *Postharvest Biology and Technology,* 86: 45–52.

Liplap P, Vigneault C, Toivonen P, Charles MT and Raghavan GSV (2013b). Effect of hyperbaric pressure and temperature on respiration rates and quality attributes of tomato. *Postharvest Biology and Technology,* 86: 240-248.

Liu J, Sui Y, Wisniewski M, Droby S and Liu Y (2013). Review: Utilization of antagonistic yeasts to manage postharvest fungal diseases of fruit. International *Journal of Food Microbiology, doi: 10.1016/j.ijfoodmicro.2013.09.004.*

Luedeling E (2012). Climate change impacts on winter chill for temperate fruit and nut production: A review. *Scientia Horticulturae,* 144: 218-229.

Luo Z, Chen C and Xie J (2011). Effect of salicylic acid treatment on alleviating postharvest chilling injury of 'Qingnai' plum fruit. *Postharvest Biology and Technology,* 62: 115-120.

Mahajan PV, Rodrigues FAS, Motel A and Leonhard A (2008). Development of a moisture absorber for packaging of fresh mushrooms (Agaricusbisporous). *Postharvest Biology and Technology,* 48: 408-414.

Maharaj R, Arul J and Nadeau P (1999). Effect of photochemical treatment in the preservation of fresh tomato (*Lycopersicon esculentum* cv. Capello) by delaying senescence. *Postharvest Biology and Technology,* 15: 13–23.

Mahto R and Das M (2013). Effect of gamma irradiation on the physico-chemical and visual properties of mango (Mangifera indica L.), cv. 'Dushehri' and 'Fazli' stored at 20 °C. Postharvest *Biology and Technology,* 86: 447-455.

Marquenie D, Michiels CW, Van Impe JF, Schrevens E and Nicolai BN (2003). Pulsed white light in combination withUV-C and heat to reduce storage rot of strawberry. *Postharvest Biology and Technology,* 28: 455–461.

Martínez-Castellanos G, Pelayo-Zaldívar C, Pérez-Flores LJ, López-Luna A, Gimeno M, Bárzana E and Shirai K (2011). Postharvest litchi (Litchi chinensisSonn.) quality preservation by Lactobacillus plantarum. *Postharvest Biology and Technology,* 59: 172-178.

Martínez-Romero D, Alburquerque N, Valverde JM, Guillén F, Castillo S, Valero D and Serrano M (2006). Postharvest sweet cherry quality and safety maintenance by Aloe vera treatment: A new edible coating. *Postharvest Biology and Technology,* 39: 93-100.

Mastromatteo M, Mastromatteo M, Conte A and Del Nobile MA (2011). Combined effect of active coating and MAP to prolong the shelf life of minimally processed kiwifruit (Actinidiadeliciosa cv. Hayward). *Food Research International,* 44(5): 1224-1230.

Minas IS, Crisosto GM, Holcroft D, Vasilakakis M, Crisosto CH (2013). Postharvest handling of plums (Prunus salicina Lindl.) at 10 °C to save energy and preserve fruit quality using an innovative application system of 1-MCP. *Postharvest Biology and Technology,* 6: 1-9.

Mohapatra D and Mishra S (2011). Current trends in Drying and Dehydration of Foods" in 'Food Engineering' edited by Siegler BC (Series: *Food Sci. and Technology*, ISBN: 978-1-61728-913-2, *NOVA Science Publishers Inc, USA, pp:* 311-351.

Molins RA, Motarjemi Y and Käferstein FK (2001). Irradiation: a critical control point in ensuring the microbiological safety of raw foods. *Food Control,* 12: 347-356.

Mostafavi HA, Mirmajlessi SM, Fathollahi H, Shahbazi S and Mirjalili SM (2013). Integrated effect of gamma radiation and biocontrol agent on quality parameters of apple fruit: An innovative commercial preservation method. *Radiation Physics and Chemistry,* 91: 193-199.

Moy JH (1993). Efficacy of irradiation vs thermal methods as quarantine treatments for tropical fruits. *Radiation Physics and Chemistry,* 42: 269-272.

Najafi MBH and Khodaparast MHH (2009). Efficacy of ozone to reduce microbial populations in date fruits. *Food Control,* 20: 27-30.

Nanda S, Sudhakar Rao DV and Krishnamurthy S (2001). Effects of shrink film wrapping and storage temperature on the shelf life and quality of pomegranate fruits cv. Ganesh. *Postharvest Biology and Technology,* 22: 61-69.

Niemira BA, Fan X and Sokorai KJB (2005). Irradiation and modified atmosphere packaging of endive influences survival and regrowth of Listeria monocytogenes and product sensory qualities. *Radiation Physics and Chemistry,* 72: 41-48.

Palanimuthu V, Rajkumar P, Orsat V, Gariépy Y and Raghavan GSV (2009). Improving cranberry shelf-life using high voltage electric field treatment. *Journal of Food Engineering,* 90: 365-371.

Pan J, Vicente AR, Martinez GA, Chaves AR and Civello PM (2004). Combined use of UV-C illumination and heat treatment to improve postharvest life of strawberry fruit. Journal of Science, *Food and Agriculture,* 84: 1831–1838.

Pandey N, Joshi SK, Singh CP, Kumar S, Rajput S and Khandal RK (2013). Enhancing shelf life of litchi (Litchi chinensis) fruit through integrated approach of surface coating and gamma irradiation. *Radiation Physics and Chemistry,* 85: 197-203.

Pongprasert N, Sekozawa Y, Sugaya, S and Gemma H (2011). A novel postharvest UV-C treatment to reduce chilling injury (membrane damage, browning and chlorophyll degradation) in banana peel. *Scientia Horticulturae,* 130: 73-77.

Prasanna V, Prabha TN and Tharanathan RN (2007). Fruit ripening phenomena-an overview. *Critical Reviews in Food Science and Nutrition,* 47: 1–19.

Ramos B, Miller FA, Brandão TRS, Teixeira P and Silva CLM (2013). Fresh fruits and vegetables—An overview on applied methodologies to improve its quality and safety. *Innovative Food Science and EmergingTechnologies.http://dx.doi.org/10.1016/j.ifset.2013.07.002.*

Rogiers SY and Knowles NR (1998). Effects of storage temperature and atmosphere on saskatoon (Amelanchieralnifolia Nutt.) fruit quality, respiration and ethylene production. *Postharvest Biology and Technology,* 13: 183-190.

Rojas-Graü MA, Raybaudi-Massilia RM, Soliva-Fortuny, RC, Avena-Bustillos, RJ, McHugh TH and Martín-Belloso O (2007). Apple puree-alginate edible coating as carrier of antimicrobial agents to prolong shelf-life of fresh-cut apples. *Postharvest Biology and Technology,* 45: 254-264.

Romanazzi G, Nigro F and Ippolito A (2008). Effectiveness of a short hyperbaric treatment to control postharvest decay of sweet cherries and table grapes. *Postharvest Biology and Technology,* 49: 440-442.

Romanazzi G, Nigro F, Ippolito A and Salerno M (2001). Effect of short hypobaric treatments on postharvest rots of sweet cherries, strawberries and table grapes. *Postharvest Biology and Technology,* 22: 1-6.

Ross AIV, Griffiths MW, Mittal GS and Deeth HC (2003). Combining non-thermal technologies to control foodborne microorganisms. *International Journal of Food Microbiology,* 89: 125-138.

Ruenroengklin N, Yang B, Lin H, Chen F and Jiang Y (2009). Degradation of anthocyanin from litchi fruit pericarp by H2O2 and hydroxyl radical. *Food Chemistry,* 116: 995-998.

Sapers GM (2009). "Disinfection of Contaminated Produce with Conventional Washing and Sanitizing Technology" in *The Produce Contamination Problem,* pg 393-424.

Saucedo-Pompa S, Rojas-Molina R, Aguilera-Carbó A F, Saenz-Galindo A, de La Garza H, Jasso-Cantú D and Aguilar CN (2009). Edible film based on candelilla wax to improve the shelf life and quality of avocado. *Food Research International,* 42: 511-515.

Sayyari M, Babalar M, Kalantari S, Serrano M and Valero D (2009). Effect of salicylic acid treatment on reducing chilling injury in stored pomegranates. *Postharvest Biology and Technology,* 53: 152-154.

Scannell AGM, Hill C, Ross RP, Marx S, Hartmeier W and Arendt EK (2000). Development of bioactive food packaging materials using immobilised bacteriocinsLacticin 3147 and Nisaplin®. *International Journal of Food Microbiology,* 60: 241-249.

Serrano M, Martínez-Romero D, Castillo S, Guillén F and Valero D (2005). The use of natural antifungal compounds improves the beneficial effect of MAP in sweet cherry storage. Innovative *Food Science and Emerging Technologies,* 6: 115-123.

Serrano M, Martínez-Romero D, Guillén F, Valverde JM, Zapata PJ, Castillo S and Valero D (2008). The addition of essential oils to MAP as a tool to maintain the overall quality of fruits. *Trends in Food Science and Technology,* 19: 464-471.

Sharkey PJ and Peggie ID (1984). Effects of high-humidity storage on quality, decay and storage life of cherry, lemon and peach fruits. *Scientia Horticulturae,* 23: 181-190.

Sharma M, Jacob JK, Subramanian J and Gopinadhan P (2010). Hexanal and 1-MCP treatments for enhancing the shelf life and quality of sweet cherry (Prunusavium L.). *Scientia Horticulturae,* 125: 239-247.

Shin Y-J, Song H-Y and Song K (2012). Effect of a combined treatment of rice bran protein film packaging with aqueous chlorine dioxide washing and ultraviolet-C irradiation on the postharvest quality of 'Goha' strawberries. *Journal of Food Engineering,* 113: 374-379.

Sivakumar D and Korsten L (2006). Influence of modified atmosphere packaging and postharvest treatments on quality retention of litchi cv. Mauritius. *Postharvest Biology and Technology,* 41: 135-142.

Sivakumar D and Korsten L (2010). Fruit quality and physiological responses of litchi cultivar McLean's Red to 1-methylcyclopropene pre-treatment and controlled atmosphere storage conditions. LWT - *Food Science and Technology,* 43: 942-948.

Sivakumar D, Arrebola E and Korsten L (2008).Postharvest decay control and quality retention in litchi (cv. McLean's Red) by combined application of modified atmosphere packaging and antimicrobial agents, *Crop Protection,* 27: 1208-1214.

Sothornvit R and Pitak N (2007). Oxygen permeability and mechanical properties of banana films. *Food Research International,* 40: 365-370.

Sothornvit R and Rodsamran P (2008). Effect of a mango film on quality of whole and minimally processed mangoes. *Postharvest Biology and Technology,* 47: 407-415.

Tatsuki M, Hayama, H, Yoshioka, H and Nakamura, Y (2011). Cold pre-treatment is effective for 1-MCP efficacy in 'Tsugaru' apple fruit. *Postharvest Biology and Technology,* 62: 282-287.

Tzortzakis N, Singleton I and Barnes J (2008). Impact of low-level atmospheric ozone-enrichment on black spot and anthracnose rot of tomato fruit. *Postharvest Biology and Technology,* 47: 1-9.

Ukuku DO (2004). Effect of hydrogen peroxide treatment on microbial quality and appearance of whole and fresh-cut melons contaminated with Salmonella spp. *International Journal of Food Microbiology,* 95: 137-146.

Utto W, Mawson AJ and Bronlund JE (2008). Hexanal reduces infection of tomatoes by Botrytis cinerea whilst maintaining quality, *Postharvest Biology and Technology,* 47: 434-437.

Valero D, Valverde JM, Martínez-Romero D, Guillén F, Castillo S and Serrano M (2006). The combination of modified atmosphere packaging with eugenol or thymol to maintain quality, safety and functional properties of table grapes. *Postharvest Biology and Technology,* 41: 317-327.

Vermeiren L, Devlieghere F, van Beest M, de Kruijf N and Debevere J (1999).Developments in the active packaging of foods. *Trends in Food Science and Technology,* 10: 77-86.

Villalobos-Acuña MG, Biasi WV, Mitcham EJ and Holcroft D (2011). Fruit temperature and ethylene modulate 1-MCP response in 'Bartlett' pears. *Postharvest Biology and Technology,* 60: 17-23.

Walkling-Ribeiro M, Noci F, Cronin DA, Lyng JG and Morgan DJ (2009). Antimicrobial effect and shelf-life extension by combined thermal and pulsed electric field treatment of milk. *Journal of Applied Microbiology,* 106: 241–248.

Wani AM, Hussain PR, Meena RS and Dar MA (2008). Effect of gamma-irradiation and refrigerated storage on the improvement of quality and shelf life of pear (Pyruscommunis L., Cv. Bartlett/William). *Radiation Physics and Chemistry,* 77: 983-989.

Yamane M, Abe D, Yasui S, Yokotani N, Kimata W, Ushijima K, Nakano R, Kubo Y and Inaba A (2007). Differential expression of ethylene biosynthetic genes in climacteric and non-climacteric Chinese pear fruit. *Postharvest Biology and Technology*, 44: 220–227.

Yang H, Wu F and Cheng J (2011). Reduced chilling injury in cucumber by nitric oxide and the antioxidant response. *Food Chemistry,* 127: 1237-1242.

Yang SF and Hoffman NE (1984). Ethylene biosynthesis and its regulation in higher plants. *Annual Review on Plant Physiology,* 35: 155-89.

Yang Z, Cao S, Cai Y and Zheng Y (2011). Combination of salicylic acid and ultrasound to control postharvest blue mold caused by Penicilliumexpansum in peach fruit. *Innovative Food Science and Emerging Technologies,* 12: 310-314.

Zambre SS, Venkatesh KV and Shah NG (2010). Tomato redness for assessing ozone treatment to extend the shelf life. *Journal of Food Engineering,* 96: 463–468.

Zhang H, Zheng X and Su D (2006). Postharvest control of blue mold rot of pear by microwave treatment and Cryptococcus laurentii. *Journal of Food Engineering,* 77: 539-544.

Zhao R, Sheng J, Lv S, Zheng Y, Zhang J, Yu M and Shen L (2011). Nitric oxide participates in the regulation of LeCBF1 gene expression and improves cold tolerance in harvested tomato fruit. *Postharvest Biology and Technology,* 62: 121-126.

Zheng Y, Wang SY, Wang CY and Zheng W (2007). Changes in strawberry phenolics, anthocyanins, and antioxidant capacity in response to high oxygen treatments. LWT - *Food Science and Technology,* 40: 49-57.