Chapter

Harnessing the Recent Approaches in Postharvest Quality Retention of Fruits

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Abstract

Fruits are an important component of our diet. Postharvest quality retention during supply chain management is a major concern and has become a priority of today's world. Owing to this, food security is a big challenge and, to mitigate this nutritional, security is a major task. The existing technologies have brought about several desirable changes in logistics of postharvest handling of fruits. As the trend has been changing, people are moving away from synthetic treatment agents; thus, these have been replaced with eco-friendly products. Since the last few years, introduction of some environmental and consumer friendly approaches like brassinosteroids, methyl jasmonates, oxalic acid, salicylic acid, edible coatings, biocontrol agents, irradiation, and cold plasma techniques has made this line more interesting across the globe. These agents work effectively and better over traditional synthetic chemicals. Application of these formulations has been found to be better to retain the quality and fresh like appearance during storage of fruits during supply chain and storage. Thus, there is urgent need to develop some novel technologies for better establishment of fruit growing industries and their maximum retention of quality. The use of these in an integrated manner could be a better way to minimize this huge loss and maximize the quality.

Keywords: postharvest quality, respiration, fruits, novel hormones, edible coatings, enzymes

1. Introduction

Fruits are integral part of our balance diet. These provide many phytochemicals that adds variety to the diet and cure many nutrient related disorders. Food security is a major burning aspect especially in developing countries. The production has been increasing day by day but quality concept has left into backseat. Despite, increasing the food production, the postharvest shelf life and retention of quality up-to a sufficient level is still needed a lot of attention. It is well known that fruits are living commodity and more prone to postharvest decay so, they require proper management to retain quality and shelf life. The quality and shelf life of produce is affected by many preharvest factors like genotype and rootstocks [1], nutrients and foliar spray [2], quality of water [3] tree age and canopy management [4, 5] use of growth hormones and several postharvest factors like precooling, edible coatings, use of postharvest fungicides, controlled and modified storage techniques, etc. The main causes of postharvest losses are weight loss, loss of pigmentation, storage diseases and disorders and physiological changes. The rate of deterioration varies and largely depends upon intrinsic characters of produces, storage conditions and state of produces during storage [6].

The major aim of postharvest technology is to optimize and reducing the losses during unit operations by adopting the emerging technologies. There is a strong lacuna of sound postharvest management for quality retention during supply chain [7]. Existing technologies are insufficient to reduce these postharvest losses. Moreover, the awareness towards harmful chemicals, sanitizers, coatings materials and other unsafe chemicals forced the research community to invent alternatives of these technologies. To meet out the satisfactory results, several researchers applied these technologies to induce shelf life and maximize the quality of fresh fruits. These includes edible and nonedible coatings, use of salts, postharvest spray of different phytohormones, irradiation treatment, etc., but side by side, these existing technologies are being replaced with new emerging technologies. With the advancement of technology and science, many recent trends have come into existence, and they are safe to health and environment and consumer friendly. Among major recent approaches, some technologies are applied use of brassinosteroids (BRs), methyl jasmonates (MeJA), oxalic acid (OA), salicylic acid (SA), application of edible coatings and films, irradiation, use of biocontrol agents and advance storage techniques like controlled atmospheric storage and modified atmospheric packaging which really revolutionized the postharvest industry (**Table 1**). Application of these technologies proven a milestone in the supply chain management of fresh commodities and made them more market oriented by addition of some extra quality. The application methodology and concentration are specific to formulation and nature of products. Some of them are novel phytohormones which enhance the defense system of fruits and help in achieving delayed ripening and senescence. Edible coatings are also used solely or in mixture with other coatings which help in reducing the firmness and retention of quality. In addition to that, some nanomaterials, fortified materials, antimicrobials, etc. can be added to the coating mixtures which significantly reduce the microbial contamination and increase the quality. Some recent storage atmosphere techniques are available which reduce the storage disorders and also enhance the shelf life. In this chapter we jotted down the different technologies and their mechanism application, and efficacy for enhancing the quality and shelf life of the fruits.

2. Brassinosteroids

Brassinosteroids are referred as the sixth group of plants hormones [71] as well as hormone of the twenty-first century, because of its important contribution in various physiological processes [72]. At the first, this brassinolide (most active form of BRs) was extracted from the pollens of rapeseed plants (*Brassica napus*) and later on from the insect galls of chestnut and termed as "castasterone." Nowadays, many plant species are using to extract the BRs like date palm pollens, oranges pollens, loquat flower bud, seeds of persimmon and pumpkin, etc. BRs involve in many developmental process like cell division, cell elongation, vascular differentiation, photomorphogenesis, and senescence. Owing to its multiple effects, it can be used in horticulture to improve growth, yield and quality. In recent, this hormone was proved as a natural, nontoxic, and safe to environment, thus it may be used in horticultural crops to improve the quality of the produce [73]. There is several evidence that it acts as growth promoter in plants either solely or in combination with other hormones like GA3, jasmonic acid and polyamines. Several researchers carried

Name of technology	Crop with dose	Salient findings	References
BRs	Grape, mango Epi-BL (45 and 60 ng g^{-1} FW)	Enhances rate of ripening when applied exogenously	[8, 9]
	Jujube (5 μM)	Reduce senescence process in Jujube	[10]
	Strawberry (400 mm BL, 200 mm BZ)	Promote fruit ripening, fruit color development	[11]
	Grape (0.4 mg/L BRs)	Managing quality of fresh produces like more anthocyanin accumulation Reduced activities of PAL and PPO enzymes	[12] [13]
	Sweet cherry (0.2 mg L^{-1})	Better shelf life	[14]
MeJA	Peaches	Delayed ripening	[15]
	Peach (0.1 mmol L^{1}), pomegranate (0.01 mM), pineapple (10^{-3}, 10^{-4} and 10^{-5}M)	Protect from chilling injury	[16–18]
	Loquats (10 μmol/L) Strawberries (1 μmol/L)	Reduced anthracnose Inhibited rot caused by *Botrytis cinerea*	[19, 20]
	Sabrosa strawberry (8 μmol L^{-1})	Enhancing total antioxidant capacity (TAC) and antioxidant enzymes activity	[21]
	Fuji apple (2240 mg L^{-1})	Higher soluble solid content, titratable acidity and delayed fruit firmness loss	[22]
	Pineapple (1 mm)	Inhibits ethylene production, weight loss, internal browning and enhances total phenol which produces during cold storage	[23]
Oxalic acid	Mango (30 mm)	Extend storage shelf-life and suppress quality deterioration	[24]
	Ber (10 mm)	Maintain enzymatic activity of phenylalanine ammonia lyase (PAL), malondialdehyde (MDA) and superoxide dismutase (SOD)	[25]
	Mature green tomatoes	Accumulation of lycopene during the postharvest ripening	[26]
	Banana (20 mm)	Reduce the deterioration and enhances their storability of fruits	[27]
SA	Guava (600 μmol)	Improve postharvest quality and delay ripening	[28]
		Retention of firmness	[28]
		Increase the shelf life during short term storage	[29]
	Apple (2 mm)	Increasing of antioxidants	[30]
	Plum (1.5 mm)	Suppresses chilling injury by altering malondialdehyde content, and enhancing polyamine accumulation	[31]
	Apple (2.0 mmol/L)	Reduce percentage of weight loss, increase total soluble solids and limiting changes in fruit color and texture	[32]
	Mango (2.0 mm)	Reduces weight loss, maintain ascorbic acid and increase shelf life at ambient temperature	[33]

Name of technology	Crop with dose	Salient findings	References
Edible coating	Papaya (papaya leaf extract + *Aloe vera* gel 1:1)	Retained firmness Delayed peel color development Reduced weight loss	[34]
	Blueberries (SemperFresh)	Slow down weight loss	[35]
	Plum (3% alginate)	Decreased weight loss Inhibits ethylene production Slowed softening process	[36]
	Fresh-cut persimmon (pectin coating + potassium sorbate, sodium benzoate)	Inhibited browning, molds, yeasts and psychrophilic aerobic bacterial growth	[37]
	Fresh-cut oranges (*Aloe vera*, gelatin, green tea)	Prevention of weight loss, retarded the microbial growth, extended the shelf life during cold storage	[38]
	Kiwi fruit slices (*Aloe vera*)	Inhibition of microbial growth	[39]
	Strawberry (CH and CMC coatings enriched with MSO) (1%)	Decrease microbial spoilage	[40]
	Pomegranate (chitosan)	Delays the ripening	[41]
	Banana (putrescine and chitosan)	Increases in phenolic compound and antioxidant activity at the end of the storage period. 1% chitosan coating enhances postharvest quality and shelf-life of banana	[42]
	Mango beeswax and chitosan	Reduces PLW, maintained firmness and reduces the activities of hydrolysis enzymes	[43]
	Pomegranate (0.5% black seed oil)	Reducing chilling injury and controlling gray mold disease	[44]
	Apple (eucalyptus, thyme 0.6% and lemon grass oil 0.8%)	Reducing the incidence of gray and blue molds	[45]
	Mandarin (coconut oil 100%)	Enhance shelf life, quality and also delayed the mold appearance	[46]
	Strawberry (chitosan and carboxymethyl cellulose (CMC))	Effective to prevents the loss of firmness and aroma volatiles, reduces the primary and secondary metabolites	[47]
	Mangoes (five nanolayers of pectin and chitosan)	Better quality in terms of weight loss, total soluble solids and titratable acidity	[48]
	Citrus (CMC/chitosan)	Maintained fruit firmness	[49]
Irradiation	Mango, pear, peach, strawberry, Nagpur mandarin and acid lime	Delaying of ripening, reduced fruit firmness, reduced rate of respiration and ethylene and lower enzymatic activities which extend the shelf life	[50–53]
	Papaya, mango (<150 Gy)	Helpful against many quarantine pests like *Bactrocera dorsalis*, fruit fly and stone weevil	[54, 55]
	Mango	Kill third instar larva of Mexican fruit fly and Mediterranean fruit fly as a quarantine treatment	[56]
	Nagpur mandarin	Delayed the Penicillium rot with higher total soluble solids	[53]

Name of technology	Crop with dose	Salient findings	References
LEL	Citrus (70 L mol m^{-2} s^{-1}), *Vitis vinifera* (80-mol m^{-2} s^{-1})	Induce disease resistance against *Penicillium digitatum* and *Botrytis cinerea*	[57, 58]
	Strawberry, citrus, peaches (40 mol m^{-2} s^{-1}), banana (464–474 nm)	Induces fruits ripening by ethylene production	[57–59]
	Banana	Positive effect on the quality (accumulations of ascorbic acid content, total sugar and phenols)	[59]
	Strawberry (blue (470 nm) light at an intensity of 40-mol m^{-2} s^{-1})	Increase total sugar content, total phenols ascorbic acid and enhances antioxidant enzyme activities (catalase, superoxide dismutase and ascorbate peroxidase)	[60]
Biocontrol agents	Citrus and stone fruits	Control green mold in citrus and brown rot (*Bacillus subtilis*)	[61, 62]
	Strawberry, grape and banana	Antagonist against gray mold and anthracnose	[63, 64]
Cold plasma	Cashew apple juice (30 mL/min)	Increase the sucrose content whereas reduces the glucose and fructose	[65, 66]
	Cut kiwifruit (dielectric barrier discharge, at 15 kV for 10–20 min)	Helpful in color retention and reduction of darkened area formed during storage	[67]
	Sour cherry, pomegranate juice (at 25 kHz, Ar, 0.75–1.25)	Increases the anthocyanin content in some fruit juices	[68, 69]
	Mandarin (2.45 GHz, 900 W, 1 L/min, 0.7 kPa, N_2, He, $N_2 + O_2$ (4:1) for 10 min)	Increases antioxidant activity, total phenolic content and also inhibits *Penicillium italicum*	[70]

Table 1.
Application of different approaches to extend the quality and shelf life of fruits.

out experiments on postharvest applications and got success to found significant achievements. A well understand correlation has been established between BRs and ripening in the fruits. Their applications alter the ripening related genes, resulting regulation in ripening and senescence. It enhances rate of ripening when applied exogenously in grape 0.4 mg L^{-1} [8], mango at the rate of 45 and 60 ng per gram of fresh weight [9], tomato in the concentration of 3 μmol L^{-1} [74] and arrest the senescence process in Jujube at a specific concentration (5 μM) [10]. However, majority of author reported that action of BRs is concentration specific and varies from nanograms to milligrams. Schlagnhaufer et al. [11] observed in his experiment that BRs application enhanced the ripening process by stimulating ethylene biosynthesis between methionine and ACC pathway. BRs (@400 mm BL, 200 mm BZ) involved in fruit color development of strawberry by expressing BR receptor, gene (*FaBRI1*) during initial red color development [12]. The applied BRs is also helpful in managing quality of fresh produces like more anthocyanin accumulation in grapes [71], reduced activities of PAL and PPO enzymes [13]. Roghabadi and Pakkish [14] found better shelf life of "Tak Danehe Mashhad" sweet cherry, when treated with BRs at the rate of 0.2 mg L^{-1}.

3. Methyl jasmonate (MeJA)

Jasmonic acid (JA) and its methyl ester (methyl jasmonate (MeJA)) are types of endogenous phytohormones that have distinct and potentially useful properties which affect plant growth and development in response to environmental stresses. Methyl jasmonate (MeJA) was discovered in *Jasminum grandiflorum* flower extracts in 1962 as a sweet-smelling compound [75]. It has inhibitory effect on ethylene biosynthesis and delayed ripening of peaches [15]. Application of jasmonate has been found effective to protect from chilling injury in many fruits crops, such as peach (@ 0.1 mmol L^{-1}) [16], pomegranate (@ 0.01 mM) [17], and "Smooth Cayenne" pineapple (@10^{-3}, 10^{-4} and 10^{-5} M) [18]. It has been discovered that exogenous treatment with MeJA enhances antioxidant capacity of different harvested fruits and horticultural crops [17, 76]. Applied MeJA also controls the postharvest diseases and decay of fruits. It was observed that application of 10 μmol/L, MeJA effectively reduced anthracnose in loquats [19] and inhibited rot caused by *Botrytis cinerea* in strawberries when treated with 1 μmol L^{-1}. [20] It has good potential to enhance the postharvest life of Sabrosa strawberry fruit (@8 μmol L^{-1}) [21]. Aglar and Ozturk [22] found that application of 2240 mg L^{-1} MeJA on fruits of Fuji apple had higher soluble solid content, titratable acidity and delayed fruit firmness loss. Boonyaritthongchai and Supapvanich [23] observed in pineapple that treatment of fruits with 1 mM MeJA inhibits ethylene production, weight loss, internal browning and enhances total phenol which produces during cold storage.

4. Oxalic acid

Oxalic acid (OA) is an organic compound which is chemically $C_2H_2O_4$. It naturally occurs in some fruits such as carambola, bilimbi, ripe papaya and kiwifruit. Oxalic acid has main role in regulating the physiology of many processes and various biochemical pathways inside the plants. It helps to increase the photosynthetic ability of plants, thereby cause increase in total soluble solids, sugars and titratable acidity. Oxalic acid reduces the production of polygalacturonase (PG) and pectin methyl esterase (PME), which are responsible for cell wall degradation, so that the treated fruit maintains the firmness in plum [77]. Zheng et al. [24] found that postharvest application of oxalic acid (@30 mM) could be a promising method to extend the storage shelf-life and suppress quality deterioration of mango fruit. It was observed in ber cv. Gola that fruit treated with 10 mM oxalic acid found to be best in maintaining enzymatic activity of phenylalanine ammonia lyase (PAL), malondialdehyde (MDA) and superoxide dismutase (SOD), their minimum values were observed with this treatment [25]. Li et al. [26], observed in mature green tomatoes that postharvest application of OA increased accumulation of lycopene during the postharvest ripening which may be due to upregulation of the expression of genes that codified for enzymes involved in carotenoid biosynthesis. Huang et al. [27] reported that dipping of banana in 20 mM oxalic acid for 10 min followed by storage at room temperature, reduced the deterioration and enhances their storability of fruits.

5. Salicylic acid

Salicylic acid (SA) or ortho-hydroxybenzoic acid is a pervasive, natural simple phenolic compound, which is frequently disseminated in plants and involved in the regulation many catabolic activities in fruits and vegetables. It is considered as a safe chemical compound for postharvest application. It has been used to improve postharvest quality such as delay ripening and retention of firmness in guava

(@600 μmol) [28, 29]) and increasing of antioxidants (@ 2 mM) in apple [30]. The application of 1.5 mM SA suppresses the chilling injury by altering malondialdehyde content and enhancing polyamine accumulation in plum [31]. Atia et al. [32], reported that the GA3 and SA treatments (2.0 mmol/L) reduced the percentage of weight loss, increase total soluble solids and efficient in limiting the changes in fruit color and texture in apple fruits. Mandal et al. [33] found that treatment of mango fruits with SA 2.0 mM reduces weight loss, maintain ascorbic acid and increase shelf life at ambient temperature. It is suggested that 600 μmol salicylic acid is beneficial to increase the shelf life of guava fruit during short term storage [29].

6. Edible coatings and films

Edible coatings are the application of commercial food grade waxes or films to product surface natural glossiness in addition to or as a replacement for natural defensive waxy coatings. These provide a barrier for moisture, oxygen and solute movement for the food and extend the shelf life by decreased respiration and ethylene, there are many commercial formulations are available in market which widely applied on the surface of fruits and vegetables. Among them Citrashine, chitosan, SemperFresh, shellac wax, carboxymethyl cellulose, guar gum, lasoda gel, *Aloe vera* gel, bee wax, etc. are common. However, plant based surface coatings and extracts are more popular than those of chemically synthesized. Use of essential oils, leaf extracts and exudations also established their strong market. These can be applied directly on the produce surface due to its edible properties, biodegradability and also healthy distinct from chemical nonedible coating which leave residual effect on the product. They have antimicrobial properties and also act as barrier. It has many positive affect on fruits such as delayed ripening in pomegranate fruits [41], inhibits ethylene production and delays softening process in plum [36], retaining firmness in papaya and [34], reduces weight loss in blueberries [35], inhibits pathogenic spoilage in kiwi fruit slices [39], in fresh cut persimmon [37], in fresh cut orange [38] and in strawberry [40]. Hosseini et al. [42] observed that coating of banana fruits with putrescine and chitosan increases in phenolic compound and antioxidant activity at the end of the storage period and it was also suggest that 1% chitosan coating is effective in enhancing postharvest quality and shelf-life of banana. It was reported that treatment of mango fruits with 2% beeswax and chitosan reduces physiological weight loss, maintained firmness by reduction in respiration rate and reduces the activities of hydrolysis enzymes [43].

Similar to that of waxes, essential oils could be effective in reducing microbial load during transportation and storage. These plant-based oils, oleoresins, leaf extracts, etc. gained popularity as surface disinfectant on fresh fruits. Many researchers have investigated the effect of leaf extracts like custard apple leaf extracts, tea extracts, neem oils, thyme oil, clove oil, ocimum oil, coconut oil, lemon grass oils, *Aloe vera* extracts, and many other herbal formulations on postharvest diseases. They may helpful in reducing many diseases like gray mold of grape, strawberry, blue mold of apple and citrus, anthracnose and stem end rot in mango and citrus, etc. and found to be effective to a certain extent. The application of these oils may increase the activities of certain defense related enzymes thus beneficial in inducing resistance mechanism in fruits. The application of 0.5% black seed oil was found effective in reducing chilling injury and also controlling gray mold disease in pomegranate (Kahramanoğlu et al. [44]). Abd-El-Latif [45] reported that application of eucalyptus, thyme and lemon grass oil (at a concentration of 0.6 and 0.8%) was found effective in reducing the incidence of gray and blue molds in apple fruits. It was observed that coating of mandarin fruits with pure coconut oil (100%) enhance their shelf life, quality and also delayed the mold appearance (Nasrin et al. [46]).

Recently, a new approach of edible coating “layer by layer coating (LBL)” is getting attention which is an electrostatic deposition technique. It is worked by combining the chitosan with other polysaccharides, like carboxymethyl cellulose (CMC). The aim of LBL was effective control the properties and functionality of material by depositing oppositely charged polyelectrolytes [47]. LBL edible coating including the five nanolayers of pectin and chitosan exhibited better quality in terms of weight loss, total soluble solids and titratable acidity in Tommy Atkins’ mangoes [48]. Arnon et al. [49] reported in many citrus fruits (mandarins, “Navel” oranges, and “Star Ruby” grapefruit) that bilayer coating with CMC/chitosan slightly maintained fruit firmness. It was reported in strawberry that coating based on chitosan and carboxymethyl cellulose (CMC), (1%) found effective to prevents the loss of firmness and aroma volatiles and it also reduces the primary (involved in carbohydrate, amino acids and fatty acids metabolism) and secondary metabolites (involved in carotenoid, terpenoid, phenylpropanoid and flavonoid metabolism [47].

7. Irradiation and LED light

Fresh fruits and vegetables contain around more than 80–90% moisture. The production of fruits and vegetables has significantly reached to beyond the desired level. Despite, a significant portion of these fruits is getting spoiled due to attack of different micro-organisms during harvesting, handling and storage. Several attempts have been made to control of these microbial population. But due to risk of health hazards, nonchemical approaches emphasized over chemical methods. Food irradiation is one of the major nonthermal methods to control the disinfestations. This is a cold treatment which is highly effective against fungal, bacterial and molds. This process involves the use of ionized radiations like gamma rays, X-rays and electron beam over the food surface. Food and Drug Administration (FDA) permitted the maximum dose limit of 1 kGy for fresh fruits and vegetables [78]. Irradiation can help in delaying of ripening, reduced fruit firmness, reduced rate of respiration and ethylene and lower enzymatic activities which extend the shelf life of fruits like mango, pear, peach, strawberry, Nagpur mandarin, acid lime, etc. [50–53]. Irradiation is also helpful against many quarantine pests like *Bactrocera dorsalis* in papaya, fruit fly and stone weevil in mango [54, 55]. It was also reported that a dose of <150 Gy is sufficient to control tephritid fruit flies [55]. Similarly, Bustos et al. [56] reported that a dose of 100 and 150 Gy are enough to kill third instar larva of Mexican fruit fly and Mediterranean fruit fly in mango as a quarantine treatment. Ladaniya et al. [53] found that the irradiation dose of 1.5 kGy was delayed the Penicillium rot in Nagpur mandarin with higher total soluble solids.

Now a days, lighting based on light emitting diodes (LEDs) is one of the main emerging technologies in horticulture to enhance quality and inhibit diseases in fruits and vegetables after harvesting. LBL able to induce disease resistance in different fruit crops such as in citrus fruits against *P. digitatum*, when fruits were exposed to LBL for 3 days with 70 l mol m^{-2} s^{-1} (Ballester and Lafuente [57]), in *Vitis vinifera* against *B. cinerea* at 80-mol m^{-2} s^{-1}(Ahn et al. [79]). LED blue light induces fruits ripening by ethylene production in strawberry, in citrus fruits (Ballester and Lafuente [57]), in peaches at 40 mol m^{-2} s^{-1} (Gong et al. [58]) and in banana at 464–474 nm (Huang et al. [59]). Likewise it was found that LED light had positive effect on the quality in terms of the accumulations of ascorbic acid content, total sugar and phenols in banana (Huang et al. [59]), increase total sugar content, total phenols ascorbic acid and enhances antioxidant enzyme activities (catalase, superoxide dismutase and ascorbate peroxidase) in strawberry (blue (470 nm) light at an intensity of 40-mol m^{-2} s^{-1}) (Xu et al. [60]).

8. Use of bio control agents

All fruits and vegetables are prone to fungal and bacterial infection during storage. Due to postharvest microbial infection a significant part of fresh produce is lost during the handling, transportation and storage [80, 81]. The high moisture content and injuries make them more perishable and susceptible against microbial spoilage. Some postharvest diseases cause major breakdown in whole bulk and reduce the value of produce. The major postharvest diseases include soft rot, gray mold, anthracnose, stem end rot, blue mold, green mold, etc. that may cause huge loss. Several chemical and nonchemical approaches implemented to reduce the above said infection and to control of diseases. However, nonchemical approaches are getting more attention including use of essential oils, plant extracts and other plant based fungicides, use of bioagents. The use of bioagents is more helpful and ecofriendly approach in this line which has host specific mechanism. In this food safety line, several products were made by isolating different microorganism which as parasitic mechanism against wide range of disease causing harmful microorganisms. Some of the commercially available bioagents formulations are given in the **Table 2**.

Uses of some safe bioactive compounds have been proved beneficial in bringing down the physiological activities of fruits during transportation, storage and minimizing the overall qualitative and quantitative losses. Many antagonist species have been identified and inoculated over various fruit surface to control several disease causing microorganisms. It was reported that *Bacillus subtilis* can be used to control green mold in citrus and brown rot of stone fruits [61, 62]. Another species *Trichoderma harzianum* act as antagonist against gray mold of strawberry, grape and anthracnose of banana [63, 64]. The use of present natural mechanism of disease control could be proven a better alternatives without harm to environment and human.

Name of products	Available commercial formulation
Serenade	*Bacillus subtilis*
Messenger	*Erwinia amylovora*
Biosave	*Pseudomonas syringae*
Aspire	*Candida oleophila*

Above formulations are on the basis of availability in the market with their commercial formulations.

Table 2.
Some common commercially available bioagents formulations.

9. Cold plasma technique (CPT)

This is a nonthermal technique that has many applications in food industry. It reduces the pathological load and deactivates the enzymatic reactions thus enhances the shelf life. The most of research work has been carried out to find out the effect of CPT on microbial decontamination rather than the quality aspect [65]. Plasma generates an electromagnetic energy which ionizes the gases, however, the energy generates by the CP is different for different purposes like packaging, plastic and polymer industries. In food technology, it is widely used for surface decontamination that is achieved by placing the foods in strong electric zone resulting generates of reactive gas species that could alter the quality and sensory attributes [65].
CP technique has great impact on the quality of fruits and vegetables. It increase the sucrose content whereas reduces the glucose and fructose and this might be

attributed to high degree of polymerization in cashew apple juice (@ PE-100, 80 kHz, N_2, 10–50 mL/min, 5–15 min, 30 kPa) [65, 66]. CP has no significant effect on ascorbic acid content of the fruits and vegetables in many fruits like kiwi [67].

It was observed that exposure of CP increases the anthocyanin content in some fruit juices such as sour cherry (Garofulić et al. [68]), pomegranate juice (at 25 kHz, Ar, 0.75–1.25 dm^3/min for 3–7 min) Kovaˇcevi′c et al. [69]. CP treatment (dielectric barrier discharge, at 15 kV for 10–20 min) has also helpful in color retention and reduction of darkened area formed during storage of cut kiwifruit, though an immediate effect of CP treatment was slight loss of pigment which might be due to the degradation of pigments like chlorophyll and anthocyanin (Ramazzina et al. [67]). Won et al. [70] reported that CP treatment (at 2.45 GHz, 900 W, 1 L/min, 0.7 kPa, N_2, He, $N_2 + O_2$ (4:1) for 10 min) increases the antioxidant activity, total phenolic content and also inhibits *Penicillium italicum* in mandarin.

10. Conclusions

The present available technologies are getting popularity and commercial potency owing to their effectiveness, safe, cheaper, wide range and easier application methods. However, their effectiveness depends on many factors viz. formulations, nature of products and applied methodology, etc. Application of novel hormones like BRs, OA, MeJA, etc. reduces the spoilage, incidence of disorders and increase quality of produces. Use of edible coatings and some recent methodology like layer by layer coatings and their combinational effects are much more helpful in extending the shelf life of produce. Essential oils and plant extracts also found helpful in reducing the incidence of certain postharvest diseases and disinfections. Now a day, exposure of fruits to LED light could be effective in inducing phenols, antioxidants and delaying senescence process. Additionally, antimicrobial compound and some nanocomposite materials could be applied over the surface. Natural antagonistic mechanism through the application of bioagents is really helpful in maintaining ecological balance along with effective disease management. Some, newly induced technologies like cold plasma and irradiation is also helpful in minimizing disinfestation against quarantine pests and increasing the quality. So, overall effects of these technologies solely or in combination could reduce the postharvest losses and preserve the quality during supply chain management. However, there is great scope left to be carried out research and invention of new technologies with higher efficiency, ecofriendly and having broader spectrum against different postharvest losses.

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